Nathl. Jennings

MONTHLY NOTICES

OF THE

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MONTHLY NOTICES

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ROYAL ASTRONOMICAL SOCIETY,

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VOL. XLIX. NOVEMBER 9, 1888. No. 1

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Thomas Bolton, 8 Carlton Terrace, St. Martin's Square, Scarborough;
Andrew Claude de la Cherois Crommelin, B.A., Trinity College, Cambridge; and
Arthur Herbert Leahy, M.A., Pembroke College, Cambridge,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

Henry Lord Boulton, Carácas, Venezuela (proposed by Sir H. Grubb);
Ernest William Brown, B.A., Christ's College, Cambridge (proposed by G. H. Darwin);
Samuel Fellows, Tynwald Villas, Lower Villier Street, Wolverhampton (proposed by Joseph Hough);
John James Lewis Goodridge, Bevis Mount, Southampton (proposed by John Newton);
Frederick William Nash, Holmesdale, Birchfield Road, Birmingham (proposed by James Leigh);
Jesse S. Nimkey, The Cottage, Sewardstone, Waltham Abbey, Essex (proposed by Herbert Sadler);
William Schooling, Brechin House, Rivercourt, Hammersmith (proposed by James S. Cooke).

The Numerical Lunar Theory. By Sir G. B. Airy, K.C.B.

(*Extract from a letter to Mr. Knobel.*)

You will remember that some months ago I stated to you that I had discovered an important error in my Lunar theory (the use of one large term only, where I ought to have used two). I have satisfied myself that I cannot remedy this without a greater amount of labour than I am able to give to it at present. From yourself, and from the Royal Astronomical Society, I have received every mark of sympathy with my exertions, and I therefore deem it my duty, at whatever pain to myself, to state to you, and through you to the Royal Astronomical Society and to the scientific world, the failure of my enterprise. It would be useless now to attempt any more detailed explanation of the cause of this failure.

I keep up my attention to the general subject, but with my advanced age (eighty-eight) and failing strength, I can scarcely hope to bring it to a satisfactory conclusion. I will only further remark that I believe the plan of action which I had taken up would, if properly used, have led to a comparatively easy process, and might in that respect be considered as not destitute of all value. . . .

The White House, Greenwich:
1888, *October* 10.

Results of Recent Investigations of Stellar Parallax, made at the University Observatory, Oxford. By the Rev. Professor Pritchard, D.D., F.R.S.

It may be interesting to the Society to be informed respecting the present condition of the work on Stellar Parallax by means of the photographic process, which I have already described in previous communications.

The scheme adopted aims at obtaining in the first instance the "parallax," in the sense in which that term is generally understood, of those stars of the second magnitude which have a suitable declination for observation at Oxford. The parallaxes of those of the first magnitude have already been derived by various astronomers, and very recently have been the subject of investigation by Dr. Elkin with the heliometer.* Such a scheme, if carried out with perseverance and success, cannot fail to contribute in a sensible degree towards our knowledge of what Herschel called the "construction of the heavens."

The results of the application of the method to the two stars constituting 61 *Cygni* have been given in a previous communica-

* Report for the year 1887–8 of the Board of Managers of the Observatory of Yale University.

tion. The same process has been more recently applied here to *μ Cassiopeiæ* and *Polaris*. Inasmuch as the process is novel, the whole detail of the work will be published *in extenso*, under the auspices of the Board of Visitors of the Oxford University Observatory. The fasciculus in which these details will be given is very nearly completed for the press.

Besides the parallaxes of these four stars, which in all respects are complete, a provisional determination has been arrived at for *α*, *β*, and *γ Cassiopeiæ*. Further, the necessary photographic plates have been secured for completing the investigation of the parallaxes of *α Cephei* and of *γ* and *ε Cygni*. To these should be added *α Coronæ*, *α* and *β Andromedæ*, making altogether, and including the four stars already mentioned, thirteen stars, the discussion of the parallax of which will be immediately proceeded with, and carried on concurrently with the observation of another batch of second-magnitude stars. I now enumerate these details mainly for the purpose of indicating the capacity of the new method, and the advance already made in its application. If persevered in, it is expected that the parallaxes of about twelve additional stars will be annually added to our present knowledge of this subject, and this I apprehend is the limit of work to be anticipated from the exertions of a single observer, with a single instrument in this climate.

Table showing the Parallaxes of Stars recently determined at the University Observatory, Oxford.

Stars of Comparison.	Magnitude of Comparison Stars.	Differential Parallax.	Probable Error of Result.	Parallax from other Authorities.	
		μ Cassiopeiæ.			
D.M. 54° No. 225	7·7	0″·0211	0″·023	Bessel	−0″·12
„ 54 „ 217	9·2	0·0501	0·027	Struve	+0·342
		Polaris.			
D.M. 88 No. 4	6·7	0·0429	0·015	Lindenau	0·144
„ 88 „ 2	8·3	0·0758	0·014	Struve & Peters	0·172
„ 88 „ 9	8·4	0·0623	0·016	C. A. F. Peters	0·067
„ 88 „ 10	9·6	0·0992	0·013		
		α Cassiopeiæ.			
D.M. 55 No. 142	8·7	0·0748	0·024		
„ 55 „ 128	9·5	0·0678	0·055		
		β Cassiopeiæ.			
D.M. 58 No. 8	8·6	0·1759	0·047		
„ 58 „ 2700	8·8	0·1484	0·056		
		γ Cassiopeiæ.			
D.M. 59 No. 137	8·8	−0·014	0·047		
„ 59 „ 150	8·9	+0·007	0·042		

An examination of the table shows that the Oxford results of some of these stars differ sensibly from those of other observers, who likewise differ greatly *inter se*. Guided by the suggestions of recent experience, I now think that such differences of "parallax" might very reasonably have been anticipated, and may properly be accepted as matters of fact, without in any degree impugning the accuracy of the observations. For in process of this work on parallax, and also from the general history of similar inquiries, it has been made abundantly evident that no necessary connection exists between the brightness of a star and its position in space or distance from the Sun. Nevertheless it is this very difference of brightness mainly which guides us in the selection of comparison stars. The "Parallax" is, in fact, and is becoming more and more generally recognised to be, a differential quantity, fainter stars being in very many instances much nearer to us than others possessing incomparably greater brightness. In passing, I may here instance *α Lyræ* as compared with 61 *Cygni*; *β Centauri* as compared with *ε Indi*.* In fact, the position in space of the faint comparison stars in relation to that of the star whose parallax is sought is, if not a matter of accident, at all events wholly unknown until the observations and computations are complete.

The case of *Polaris* in relation to the four comparison stars employed is somewhat remarkable, and I must in candour admit is not apparently in entire accordance with the preceding remark. The differential parallaxes of *Polaris* in relation to these four stars are more or less proportionate to the difference of brightness of *Polaris* and these stars. This difference of parallax so much exceeds the probable error of determination, that I propose to further pursue this somewhat novel and interesting question, by investigating the differential parallax of the comparison stars themselves with the aid of the new photographic refractor, now all but complete, at Oxford.

If these remarks be founded on fact, then any such term as "The mean Parallax" of a group of stars having the same magnitude possesses little or no scientific value, in the sense of its necessarily leading to the slightest knowledge of the parallax of any particular star in that group. In my view of the case, wherever the individual differences are so enormous, there an average of the whole is apt to be misleading and unscientific.

Possibly the researches already made, or being made, by the aid of the spectroscope may in due time lead to some natural classification of stars apart from that of magnitude or brightness. Such a classification, if it can be made, will in no degree detract from the value or dispense with the necessity of parallactic determinations.

Oxford University Observatory:
1888, *November* 8.

* Heliometer-determinations of stellar parallax in the southern hemisphere, by Drs. Gill and Elkin.

On an Instrument for Measuring the Positions and Magnitudes of Stars on Photographs and for Engraving them upon Metal Plates, with Illustrations of the Method of using the Instrument. By Isaac Roberts.

Celestial photography presents for investigation such vast numbers of stars that the necessity of finding new methods for dealing with them is pressed with force upon our attention. How we are to study the characteristics of several millions of stars is a problem pressing for immediate solution. The material for study will soon be abundantly supplied by the various international photo-astronomers when their instruments are erected, but hitherto those who are leading in this new science have apparently not advanced beyond the ideal of dealing with some two millions of the stars when they are photographed, and to them this number seems to be so large that in the lifetime of the existing generation of astronomers they can only hope to be able to leave behind them as a legacy to their successors huge volumes of figures deduced from some thousands of photographic plates.

Those successors, again, must rephotograph the heavens and in like manner produce their huge volumes of figures, and in the second or third generation from this it is anticipated that astronomers may sit down and endeavour to unravel the mysteries which may be lying hidden in the duplex series of figure volumes. This does not appear to be a satisfactory solution of the problem.

The preservation of the negatives so that they would for centuries be available for measurement and study would be a simple solution, but we know that the sensitised films on the plates that must at present be employed will not keep for centuries, and even if some future discovery should produce sensitised films that would be indestructible by lapse of time, or a method of vitrification should succeed, yet the glass plates, which of necessity would have to be frequently handled, could not be ensured against accidental destruction. Metal plates instead of glass might be coated with emulsion, and to ensure permanency each star might with a point be etched through the film and coating of wax upon the metal plates; but this method would be only the result of uncertain hand labour and would also involve the destruction of the photographs, instead of which they ought to be preserved for reference as long as possible. But without enumerating here the many difficulties which are more or less obvious and suggesting methods for the preservation of the glass negatives, we would ask, Are there not other ways of preserving with necessary accuracy the essential parts of the photographs, namely, the star positions and magnitudes? In answer to this question I submit the instrument and method which are the

subjects of this communication, and which have occupied much of my attention during the past three years.

It is well known that copper plates may with ordinary care, and by use of simple means, be preserved for centuries, and if the star images could with accuracy be transferred from the negatives, without causing them injury, on to plates of copper or other metal, and then printed, and when necessary the plates also be duplicated and placed concurrently with the astro-photographic work in the hands of the astronomers of the present day, some of us might be permitted to see a portion of the fruits of our labours instead of leaving all to future generations. With the instrument now to be described the transference of the star images on to copper plates is both practicable and susceptible of great accuracy.

Description of the "Stellar Pantograver."

Plate I. shows the form and some of the details of the instrument.

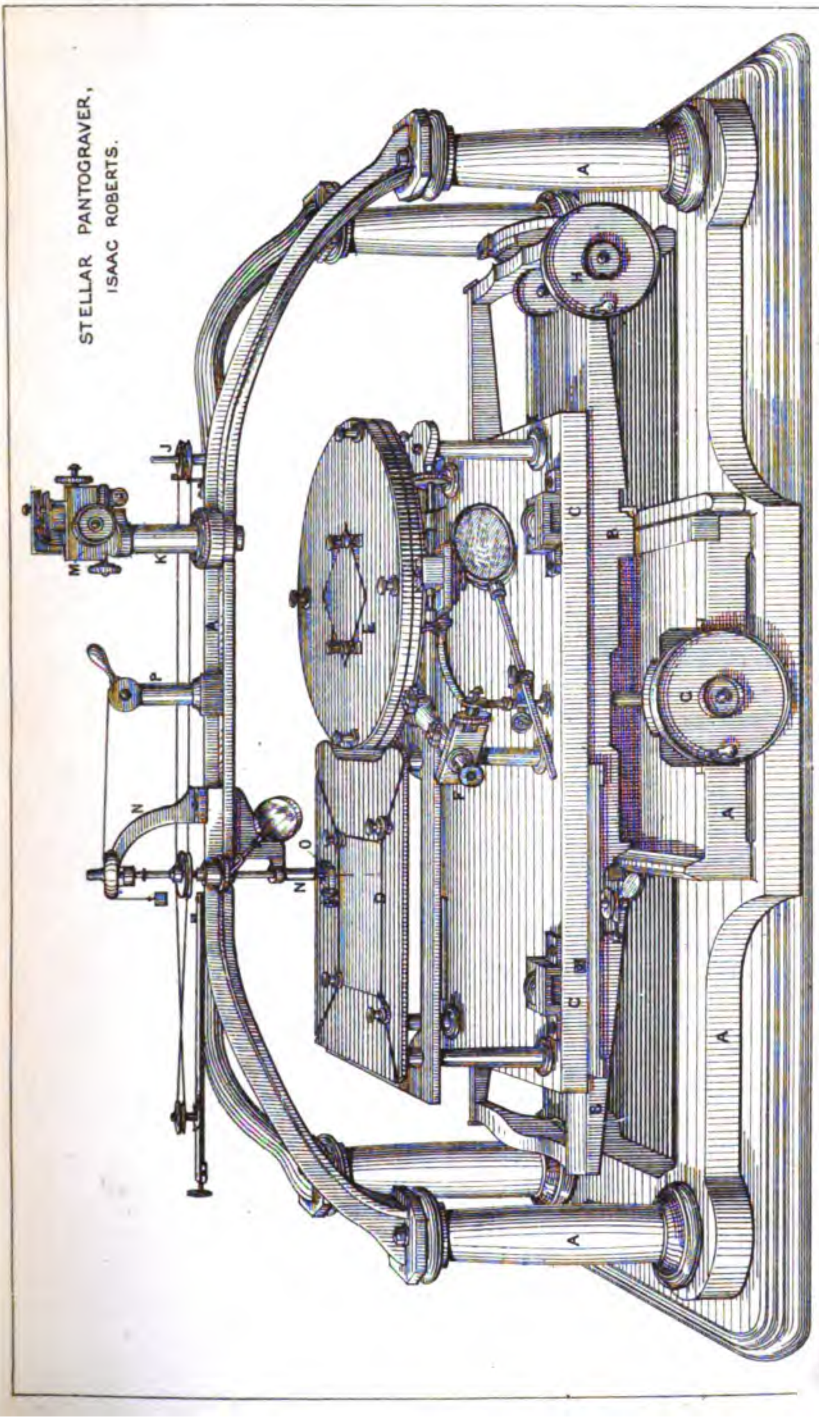
A A A A are parts of the framework. The base plate and bridge on the top are of cast iron. The pillars are of brass.

B is a cast-iron platform, freely movable upon four anti-friction rollers, and guided by a V groove to run in a direction either towards or from the operator.

C is a platform of cast iron and guided in a similar manner to B, but in a direction at right angles to it, or in other words movable in a direction either right or left of the operator. Upon the top of this platform are placed the square stage D and the circular stage E, one to hold and secure the photograph and the other the copper plate to be engraved. The circular stage E is also made to rotate and serve as a large position-circle. It is $13\frac{1}{2}$ inches in diameter, divided on the edge to degrees and five minutes of arc, and with the micrometer and microscope F can be read to seconds and fractions.

The movable platforms B and C have both a slow and quick motion. The slow motion is given by the screws of which G and H are the divided circular heads. The screws are of steel, $\frac{3}{4}$ inch in diameter, and cut 100 threads to the inch. The circular heads are five inches in diameter and divided on the edge to 100 equal parts; the value of one division is therefore 0·0001 of an inch, and by a vernier each division can be read to one-tenth, so that a distance traversed by either stage is measurable to 0·00001 of an inch.

K is a microscope bent at a right angle for convenience, and firmly held in the position shown over the circular stage E. The micrometer eyepiece M has webs which are placed at right angles to each other, and by one movement of the screw each pair of webs may be made to part asunder or to approach each other, as may be required, and form a common centre; thus each photographic star disc is viewed in the microscope with four spider webs


STELLAR PANTOGRAVER,
ISAAC ROBERTS.

CIRCLES DRAWN BY ROBERTS'

PANTOGRAVER.

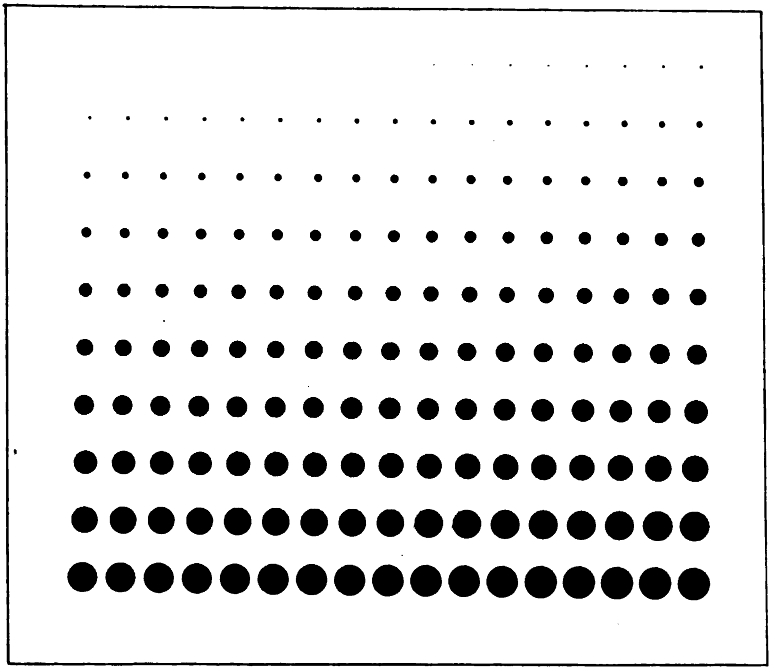
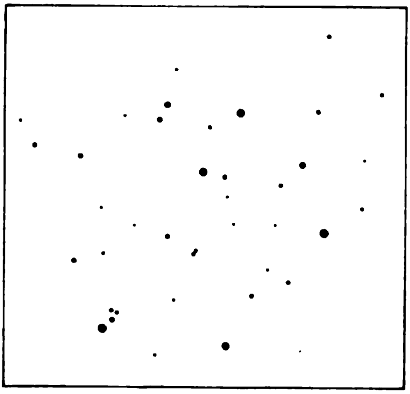


PLATE III.

ENGRAVED
FROM A NEGATIVE OF THE
·PLEIADES·
by PROF. PRITCHARD.



placed tangentially against its margin, and the common centre of the webs is the centre of the star disc. The diameter of the star disc is measured to 0·0001 of an inch upon the heads of the screws of the micrometers. Two measurements at right angles are taken simultaneously, thus checking each other and at the same time showing if the star disc is round, together with the extent of deviation, if any, from the circular.

N is the engraving tool. It consists of a vertical steel shaft in gun-metal bearings. On the lower end of the shaft is fixed a micrometer, with screw cut 100 threads to the inch and head divided into 100 equal parts. The measurements are therefore made to 0·0001 of an inch, like those of the eyepiece micrometer. On the under side of the micrometer O is a steel pin carrying a fine diamond point, which is the graver, and it is fixed to a sliding piece attached to the micrometer screw, by the turning of which it is moved eccentrically to the extent required to trace a circle which is either equal to or is any proportion required of the star diameter on the negative. The readings of this micrometer are double those of the eyepiece micrometer, and by inspection and rotation of the heads of both these micrometers circles of any diameter from a point up to 0·16 of an inch can be traced with the diamond point of the graver.

P is a lever to lift the graver off the plate.

J is the wheel for rotating the graver.

Plate II. shows 160 circles which were traced upon copper, and afterwards transferred to lithographic stone and printed. The largest of the circles measures 0·16 of an inch in diameter, and each successive circle is 0·001 of an inch smaller in diameter than the one preceding it. The last is a point. The instrument is graduated so that circles can be drawn which will be either smaller or larger in diameter than each other within the limits of measurement.

From the foregoing statements it is apparent that a degree of accuracy in drawing stellar positions and magnitudes from the negative should practically be equal to the original negative, and, in order to demonstrate the closeness of theory with practice in this matter, I applied to Professor Pritchard for the loan of one of his negatives of the *Pleiades*, so that I might engrave the stars on copper plate, and he obligingly sent one that had been exposed for the same time as those used in the general determination of parallax; moreover he measured the engraved stars, as well as those which have been printed from the copper plate upon paper and shown in Plate III.

The following table gives the results of his measurements:—

Results of Measurement of Star Distances on the Copper Plate of Pleiades compared with those of the Original Negative.

Names of Stars Measured (Bessel's Notation).			Distance on Negative in Inches.	Distance on Copper Plate in Inches.	Difference in Inches.	Difference in Arc.
			in.	in.	in.	"
From Maia	to	No. 4	0·11703	0·11609	0·00094	1·63
,,	,,	Celeno	0·51980	0·51876	0·00104	1·80
,,	,,	Electra	0·70567	0·70528	0·00039	0·67
,,	,,	Wolf, No. 47	0·85096	0·85064	0·00032	0·55
,,	,,	No. 1	0·72708	0·72788	0·00080	1·38
,,	,,	Merope	0·91772	0·91711	0·00061	1·06
,,	,,	No. 10	0·38450	0·38536	0·00086	1·49
,,	,,	ρ	0·90537	0·90600	0·00063	1·09
,,	,,	η	0·97170	0·97119	0·00051	0·88
,,	,,	No. 21	0·98982	0·99016	0·00034	0·59
,,	,,	Asterope	0·35427	0·35471	0·00044	0·76
,,	,,	No. 5	0·55281	0·55235	0·00046	0·80 Mean 1″·06

Average Deviation of Bisections of Star Discs on Copper Plate.

0·00009 in. or 0″·16.

Average Deviation of Bisections of Star Discs on Negative.

0·00007 in. or 0″·12.

Comparison of Measures on Paper Print with Original Negative.

Names of Stars Measured (Bessel's Notation).			Distance on Negative in Inches.	Distance on Copper Plate in Inches.	Difference in Inches.	Difference in Arc.
			in.	in.	in.	"
From Maia	to	No. 4	0·11703	0·11688	0·00015	0·26
,,	,,	Celeno	0·51980	0·51911	0·00069	1·19
,,	,,	Electra	0·70567	0·70760	0·00193	3·34
,,	,,	Wolf, No. 47	0·85096	0·85084	0·00012	0·21
,,	,,	No. 1	0·72708	0·72966	0·00258	4·46
,,	,,	No. 21	0·98982	0·99084	0·00102	1·76 Mean 1″·87

Five bisections were taken for each distance, and the mean of the five was taken.

The average discrepancy between the measures taken on the copper plate and on the negative is 1″·06.

Between the paper and the negative the average discrepancy is 1″·87.

It is found that the error (average) of bisection of a star on the original negative, compared with that on the copper plate, is as 3 : 4.

The paper print was somewhat creased and probably hygroscopic. Prof. Pritchard adds, 'I regard this first attempt as eminently successful.'

It is desirable in the engraving of stars upon copper plates, with the view of printing them, that the photographic diameters should be increased at least twofold, or some other definite proportion, for if they are drawn only to the sizes on the negatives the faint stars are very small points which are difficult to see and measure. This can be done by the instrument.

I find a magnifying power of 24 with a field of two-tenths of an inch in diameter a very convenient one for viewing the stars on the negatives for engraving.

The instrument is adapted for cutting out the interiors of the star discs after their outlines are traced on copper plates, but it is a better plan to transfer the outlines on to lithographic stone and then fill in the interiors with a pen or brush. This saves both time and cost, and, what is of still greater importance, saves the plates themselves from injury by frequent pressure and wear. Many thousands of printed copies could thus be produced from one impression taken from the copper plate.

I find by experience that I can easily engrave 50 stars in an hour. If, therefore, an engraver worked during 8 hours a day for 48 weeks in the year, he would with one instrument transfer to copper plates 115,200 stars. If 20 instruments were thus employed during 10 years, 23,040,000 stars would be permanently placed on record, so that the astronomers of the present time could do great work, and afterwards leave their data unimpaired to the scrutiny of succeeding generations of astronomers in a form available for centuries to follow. Thus we should make a valuable contribution towards the solution of the great problems: Whence came our speck of Earth? Whither is it going?

The pantograver was made under my directions by Mr. Hilger, and I highly appreciate his skill in overcoming difficulties, and also the perfection of his workmanship, without which (or their equal) the success of the method would not have been attained.

Illustrations of the Method of using the Stellar Pantograver.

The machine is constructed of a size that plates which do not exceed eleven inches square can be engraved by it, and stars or other objects can be traced by an ordinary mechanic or other person to practically the accuracy of those on the plate or negative.

In using the machine a plate of glass the size of the negative to be engraved is ruled with parallel faint lines one-tenth of an inch apart, and in the case of a plate 4 inches square each line is numbered at the ends in consecutive order from 1 to 40. The plate is placed upon the stage under the observing microscope,

with the ruled side uppermost. The negative is then placed and secured upon the glass plate with the film side down, and in contact with the ruled lines. This arrangement will ensure the stars when they are engraved upon the copper plates, and afterwards printed on paper, being in the same order of right ascension and declination as those on Argelander's chart. This, I submit, is desirable, because that chart will form a valuable key to the photographic chart, and is immediately available for the study of stellar changes.

The copper plate is next placed on the stage under the engraving point, and its position adjusted and fixed as required. As already stated the magnifying power I use in engraving is 24 diameters, and this gives a clear field of two-tenths of an inch in breadth. All the stars within the space enclosed by the lines are brought successively and accurately to the optical centre of the microscope between the four adjustable threads of the eyepiece micrometer, and the diameter or magnitude of each star is read off on the screw-head to 0·0001 of an inch. The same reading is then given to the screw-head of the engraving point micrometer. The point is then lowered to impinge upon the copper plate, and the tool handle twice rotated to cut the ring which represents the position and diameter of the star on the negative. In this way each star on the negative can be engraved both accurately and expeditiously, and without unduly taxing the attention of the operator, at the rate of 50 to 60 stars an hour. If any uncertainty should at any time arise as to whether any star has or has not been engraved, the resetting of the instrument will at once determine it, and specks or other defects in the film can with certainty be detected and eliminated.

The accuracy of the work done by the machine has been tested in various ways besides those already referred to, but the following example will suffice. Four stars at distances apart of 0·35 inch and 0·46 inch on a negative were selected and brought successively under the microscope and then engraved on a copper plate, first as a point in the centre of each; then a series of concentric circles were drawn round the central point, the instrument being moved freely by hand in any direction between each operation of drawing the central point and circles. At the completion of the operations the circles were practically concentric with the central point and with each other.

Plate IV. is a chart of 1,270 stars within a circle of one degree of the North Pole as the centre, and it was engraved from a negative taken on the 14th of August this year, with an exposure of 105 minutes. The diameter of the circle is two degrees. Carrington and Argelander on their charts show 38 stars on this area, and they are distinguished on Plate IV., as nearly as I could recognise them (for they do not all coincide), by the white circles with a black spot in the centre.

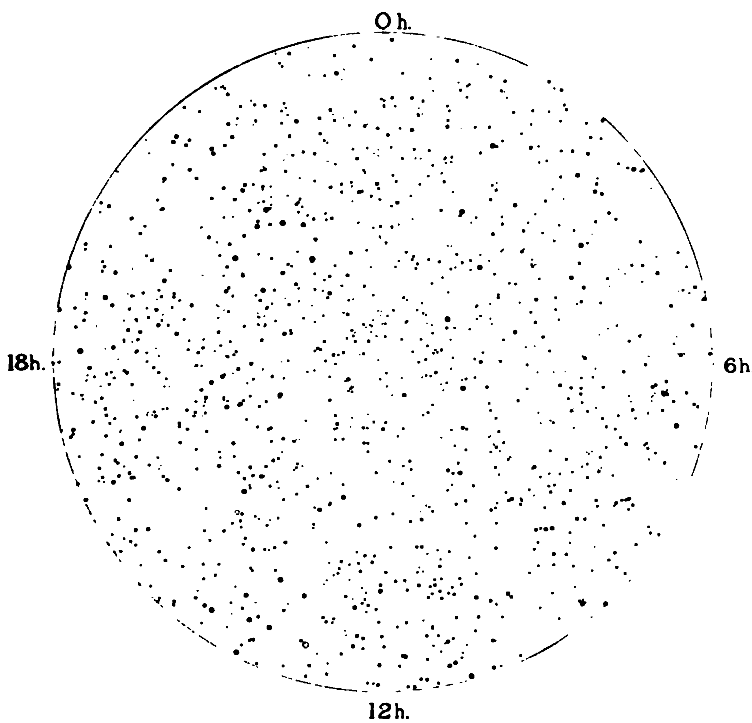
This chart of the Polar circle will serve as an illustration of

Plate IV.

Chart of North Polar Stars

by

Isaac Roberts.



Engraved from a Photograph taken on 14th August 1888. The white Stars represent those on Argelander's Chart. Circle 2° Diameter.

the importance to working astronomers of this method of engraving, printing, and circulating without delay the work of the photo-astronomers, both international and private, for it places in their hands a strongly marked index showing them at a glance the exact spots in the sky, where perceptible changes in the positions and magnitudes of the stars have taken place since the dates of the several published charts.

The fact being established by inspection, measurements, or eye alignments that changes according to the charts have taken place among the stars, there is obvious necessity for measuring the negative or copper plate and use of the transit instrument, and in a few months' time after publication of the photographic chart there will be ample work for all the astronomers in the world to determine whether those differences are due to actual changes in the objects or to errors in the charting, and then will follow computations and evolution of laws which will occupy their lifetime and those of succeeding generations of astronomers.

These suggestions for immediately utilising the existing charts by comparison with the photographic chart, would suggest that modifications should be made in the international scheme for the formation of a catalogue of some two million stars, and, instead of the proposed 15 minutes' exposure of the plates, at least an exposure of 60 minutes to a clear sky ought to be substituted, and the stars charted to the faintest magnitude such an exposure would imprint even as a stain on the films. By these modifications of the scheme, a chart of the sky worthy of the resources of the present day would immediately be commenced, and within the next ten years accurately printed copies showing all stars down to the 16th or 18th magnitude would be in the hands of all persons interested in astronomical investigations.

I have now shown, and I think demonstrated, the practicability of the scheme for engraving. The question of the form in which the printed charts should be issued could be answered in at least two commendable ways: *first*, with four photo-squares on each leaf in a book of strong paper; *second*, as separate photo-squares on octavo sheets of strong paper, and numbered in consecutive order and with an index, the sheets being kept loose in book boxes containing 500 each, so as to be available for micrometric measurements. This I think would be the most convenient method, as will be seen if we proceed to consider the way that astronomers would be likely to adapt for themselves their future work, which we will assume to be somewhat in the following order, namely:—

Astronomer A is desirous of investigating the stars within the radius of one degree of the Pole as a centre, and is possessed of the printed charts and an instrument of precision for measuring. He knows in which country the photo-astronomical work of this region is done, and he also knows the bureau where the negatives and engraved plates are kept. The bureau ought to be in

a building forming part of or contiguous to the national observatory of each country, and under the control of the national astronomer. Our typical astronomer, having studied the printed chart and therein found matter requiring closer investigation, requests the head of the bureau to send him a copper-plate duplicate of the original, of the sky space indicated, and with his request remits the standard fee. In due course he receives what is practically the original negative (the copy being exact), and then resumes his investigations, and within a brief interval of time he is in a position to inform the astronomical world that he has found something new to tell.

The method hitherto followed in designating stellar magnitudes by numerals and decimal parts will not be the most desirable in the new photo-astronomy, as will be evident on examination of the microscopic gradations of the engraved circles representing the star discs. The determination of magnitude should no longer be empirical, but be the result of exact measurement by micrometer, and in place of assuming a given number of magnitudes such as 1st or 18th, there may be one hundred or more measurable magnitudes between the brightest star and the faintest on any negative or copper-plate copy, or printed chart. The future designation may be in parts of an inch or of a millimetre.

In the pantograver the eyepiece and engraving micrometers are divided to measure 0·0001 of an inch, and if the star discs on the negatives were both circular and sharply defined on the edge, estimated measurements to 0·00002 of an inch could be made and registered as the stellar magnitude; but in practice these conditions seldom occur, and the edge of the disc is undefined, by reason, probably, of atmospheric tremor and glare; hence measurements of magnitude will be $\pm$ 0·001 of an inch, and the gradations would therefore be somewhere within this limit. If the disc of the brightest star, say *Sirius*, were represented on the photograph by 0·08 of an inch, and the faintest star by 0·002 of an inch, there would by the gradation here suggested be seventy-eight measurable stellar magnitudes, each one of which would be distinctly recognisable by measurement.

The pantograver is also an instrument of precision for measuring stellar distances and position-angles. Any distance not exceeding 11 inches can be measured theoretically to 0·00001 of an inch in two directions at right angles to each other, and in my photo-telescope, which is 98 inches focal length, one second of arc is equal to 0·00476 of an inch, being a large measurable quantity.

There are many details connected with the subject-matter of this paper that I must defer for future discussion.

Chart of 1,270 North Polar Stars.

The following are the positions and magnitudes of the 38 stars on Argelander's chart, which are shown as *white circles* on the accompanying engraved photo-chart (Plate IV.).

Magnitude.	Right Ascension. h m s	Declination. ° ′ ″	Magnitude.	Right Ascension. h m s	Declination. ° ′ ″
9·5	0 11 5	89 36 2	9·5	12 0 23	89 26 3
9·2	1 17 35	0 2	8·8	12 59 20	28 3
8·8	1 49 36	29 2	8·7	13 3 53	8 7
9·4	1 50 57	23 6	9·4	13 25 6	32 6
9·5	1 51 58	13 3	9·5	15 3 47	24 2
9·4	2 16 43	0 6	9·0	15 14 45	40 9
9·3	3 11 12	4 3	9·5	15 44 3	55 1
9·5	3 53 49	0 5	9·5	15 45 16	2 8
9·1	4 49 39	27 1	8·7	17 21 38	18 4
9·5	5 43 44	6 0	9·4	18 7 27	43 8
9·5	5 57 3	3 6	9·3	18 42 30	9 5
9·1	6 17 38	37 9	9·5	19 29 17	38 0
7·0	7 3 40	1 8	9·5	19 37 46	12 9
9·5	7 14 2	1 0	9·5	19 45 0	27 5
9·2	7 27 50	1 6	9·3	19 56 5	14 3
9·5	8 58 47	39 4	9·3	20 13 29	45 9
9·0	10 26 21	32 0	9·5	21 8 21	31 7
8·9	11 8 27	43 9	9·3	22 6 40	48 0
9·5	11 9 11	32 9	9·0	23 21 18	0 8

On a Compensating Pendulum. By Richard Inwards.

The pendulum about to be described must not be taken as novel in all its parts. So much has been done that such entire novelty would now be impossible. But what I hope is that the general arrangement with its many new features may result in a substantial improvement on existing forms.

In accurate pendulums in which the temperature compensation is obtained by the expansion in contrary directions of tubes of zinc and steel, there has always been a great difficulty in at once apportioning the respective lengths of the rods or tubes used for the purpose.

This difficulty arises in a great measure from the fact that no two specimens of the metals can be readily obtained having exactly the same coefficient of expansion. Particularly with the zinc is

this the case, as one may see by consulting the different horological and mechanical text-books, where widely different figures are given as based on the experiments of various investigators.

Even in the best clocks, where the proportions of the tube-lengths have been most carefully adjusted by theory, it is often found necessary to dismount the pendulum in order to alter the length of the zinc tube.

In the Westminster clock this has, I believe, been done on at least two occasions, when pieces of zinc had to be inserted in order to bring the compensation to its present apparently perfect condition.

The zinc tube in the usual pendulum is under powerful compression in having to sustain as a pillar the whole weight of the bob, and it may be that it requires some time before its atoms settle down to a steady rate of expansion under this heavy strain. It may also be that the tube shortens a little by bending in the middle. In any case, the remedy involves stopping the clock and making up the pendulum again.

Many contrivances have been suggested for the purpose of meeting this difficulty, but all involve some disadvantages. That of Ellicott has a number of pivots and joints to be adjusted, while the plan proposed by our own esteemed Fellow, Mr. Buckney, has the disadvantage of carrying a considerable piece of surplus zinc, and of the necessity of entirely retiming the clock after the alteration. A plan proposed on somewhat similar lines by myself* is open to the same objections.

By the method now proposed the alteration in the proportionate lengths of the zinc and steel can be made at once while the clock is going, and if erroneously altered can be corrected at any time, also without stopping the clock.

This is to be done by transferring the compensating rods or tubes to the fixed part of the clock.

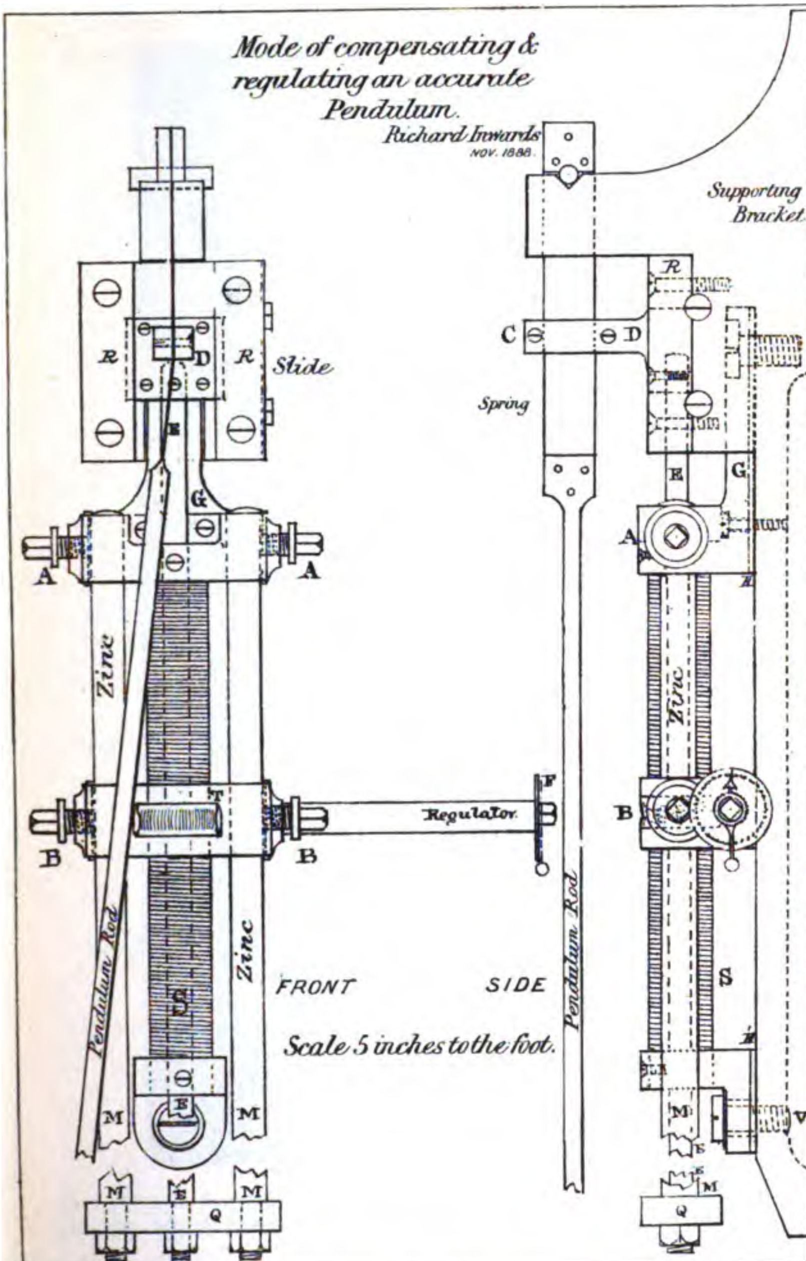
In the accompanying drawings the means of carrying out the proposed changes are depicted.

The woodcut in black shows the general arrangement of the pendulum, while the whole-page plate gives elnarged front and side views of the upper portion. The letters refer to the same parts in each diagram.

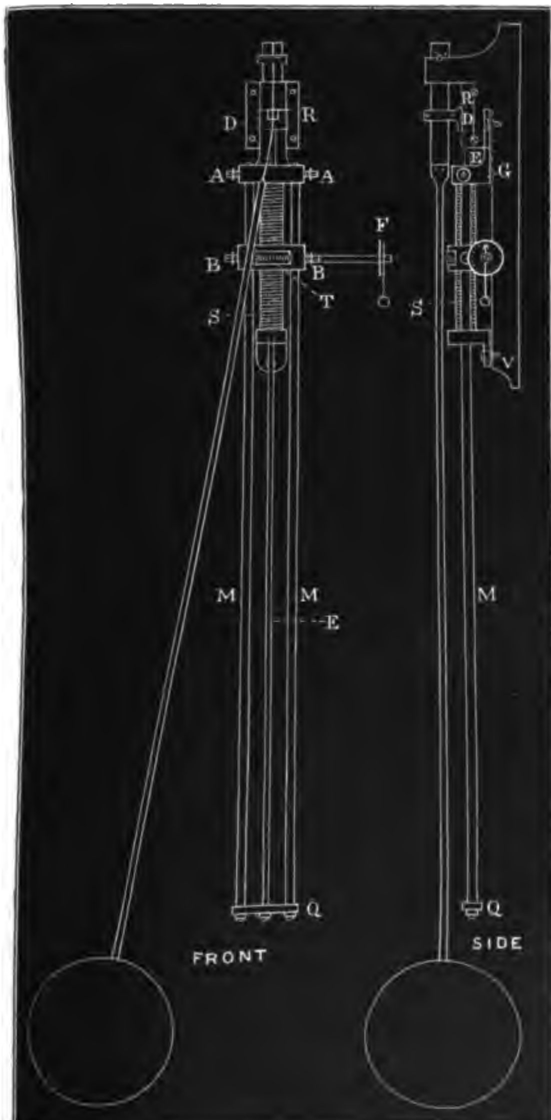
It will be seen that the pendulum is supported in the usual way from a strong cast iron projection, and is suspended by a spring of somewhat greater length than is customary.

About the middle of the spring it is grasped by a clip consisting of two arms D, which are adjusted to embrace it with sufficient closeness to hold it firmly, but loose enough to allow of movement in a vertical direction. There are screws to regulate this pressure, and I should propose to add a lining of wood or leather to the clips where they bear upon the pendulum spring. The arm D is fixed to a block which moves vertically between two slides, very similar to a smaller copy of those on a lathe slide

* *Horological Journal*, September 1886.


Mode of compensating & regulating an accurate Pendulum.
Richard Inwards
Nov. 1888.
Supporting Bracket.
Slide
Spring
Zinc
Regulator
Pendulum Rod
FRONT
SIDE
Scale 5 inches to the foot.

rest. The slide has setting screws, and ought to admit of no horizontal motion whatever. It may be remarked in passing



that there is a great distinction in steadiness between this plan and that which has been often proposed, and in which the whole

pendulum support is moved so as to pull up the spring between the fixed chops; and in which case the weight of the pendulum is carried by a movable support instead of a fixed one.

In the present plan, by the further addition to the clips of a spring stiffer than the pendulum spring, and with a similar one on the side of the sliding block D, all possibility of the smallest lateral tremor would be cut off. Another advantage of these additional springs would be that the clips would slightly yield, and so override any small impediment such as dust or a spot of rust either on the pendulum spring or on the fixed part of the slide.

The sliding block D is attached to the end of a steel rod E of small diameter (as it has scarcely any strain to bear), and of about 30 inches long, and which passes down at the back of the pendulum-rod to a point a little above the level of the bob. Here it is fixed to the middle of a bar Q, which at its ends is made fast to the two zinc rods or compensating bars MM. These are about 29 inches in length, of which about 26 inches are acting on the pendulum. The zinc rods are firmly fixed at B to a block carrying in its centre a worm-wheel of 60 notches, T.

This worm-wheel, which is a kind of nut, turns on a fixed screw S (of 18 threads to the inch), firmly attached to the supporting bracket, and prevented from turning round.

The tangent screw actuating the wheel or nut T is behind it (not seen in the drawing). The axis of the tangent screw is prolonged to F, where it carries a dial of 32 divisions, and forms the regulating apparatus by which the timing of the clock is done, as well as making such alterations in the proportions of the lengths of zinc and steel as may be found necessary.

It will be seen that if the wheel T is turned it must rise or fall on the fixed screw S, and so through the medium of the zinc and steel rods raise or depress the sliding block moving on the pendulum spring above, and so altering the length of the pendulum. This is the proposed timing adjustment, and it will be found that one division of the regulating dial F will correspond to an alteration in rate of about one second per month. This is sufficiently delicate to obviate the necessity of adding small weights to the pendulum. The adjustment is made while the clock is going, and can also be used as a means for temporarily accelerating or retarding the clock.

A mechanical friend of great experience says that in altering this dial, say, to the right one division, it should first be turned a quarter of a turn to the left, and then brought one degree forward from where it stood before. This eliminates an error which might arise from slip or from hesitancy in moving.

Now to alter the proportion of zinc in the pendulum nothing more is necessary than to *first* tighten the binding screws AA (which must always be loose at other times), and then to slacken the screws BB. The effect of this is to release the regulator

from all connection with the pendulum, and make the zinc rods practically a part of the fixed bracket or support. Then by turning the regulating dial the effect will be that the worm-wheel T simply travels up or down the fixed screw, and changes the position of the binding screws B (now loose) with respect to the zinc rods. When this position has been altered so as to add or take away sufficient of the length, the screws B must be tightened while A A must be loosened (or perhaps, better taken away till wanted).

It will be seen on carefully studying this plan that the upper part of the steel rod E is balanced as regards expansion by the expansion in a contrary direction of the support G and that of the part of the screw S above the tangent wheel.

G must therefore be of steel, so must S; and it is well that they should be of uniform thickness, say a quarter of an inch, so as to take up heat at equal rates.

The piece G is separated from the planed bed of the bracket by slips of bone (H, H′ on plate), with the object of allowing it to behave independently of the heavier cast-iron bracket, as regards expansion. Of course the lower screw V must pass through an oval hole, and may be kept up to a working contact by placing what is known as a spring washer or bent disc of steel underneath the head of the screw.

If these suggestions are, as I hope, practical, a great many minute sources of error in the pendulum will be got rid of by this form of construction. The pendulum itself will be brought almost to its ideal form, a mere ball of lead supported by a thin stem or wire. The resistance of the air to the pendulum rod will be reduced to a minimum. The proper proportion of zinc to steel can be at once restored, even after the minute displacement which occurs in timing. No useless weight will be carried. The clock need never be stopped except for cleaning or removing, and its rate and compensation can be altered even to the most minute degree while it is going.

The zinc used should be subjected to boiling and freezing before being attached to the pendulum, especially if in the form of drawn rods or tubes.

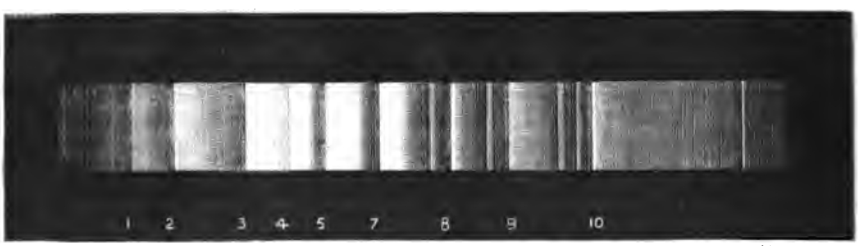
All these seem small matters, but it is with the "next to nothings" that we have now to deal, in striving to add the last perfections to our already nearly perfect timekeepers.

20 *Bartholomew Villas, N.W.:*
1888, *November* 8.

On the Spectra of R Cygni and Mira Ceti and some Stars with probably similar Spectra. By Rev. T. E. Espin.

R Cygni.—On August 13 a very bright line, apparently F, was visible in the spectrum of this star. The line was subsequently seen on several nights, and was measured and confirmed by Dr. Copeland at Dun Echt.

Mira Ceti.—During the maximum of this star the colour was very pale yellow; as soon as the maximum was passed the colour gradually inclined to orange. The accompanying drawing gives the appearance of the spectrum on October 23 in strong moonlight, and on October 30 on a dark sky, when the star had faded considerably. The observation of October 30 only added one new detail to the spectrum; this was the fact that band No. 8 in Dr. Dunér's nomenclature was really divided into two. Band No. 9 is also broken up into at least two, and band No. 10 into three. Whether these interferences in the bands are due to bright lines I am unable definitely to say.



Spectrum of *Mira Ceti*, 1888, October 23, 30.

The numbers refer to Dr. Dunér's bands.

Further away in the violet there is a brilliant line which may be the γ hydrogen line. The beauty of the spectrum is beyond anything I have seen. The spectrum was observed with a direct-vision prism before an eyepiece magnifying 200 times. By altering the distance between the prism and the eyepiece increased length of spectrum is obtained at pleasure. With the prism close to the eyepiece the spectrum of *a Orionis* consists of the usual III. type bands; by moving the prism six inches or so away from the eyepiece the bands are resolved into innumerable lines.

Since Professor Pickering discovered the bright lines in *Mira Ceti* and in Mr. Gore's star in *Orion*, I have examined very many

of the known III. type stars, but only in the case of the following have I been led to suspect a spectrum with bright lines. If the bright lines really exist in these stars they are very difficult objects. The full aperture of the $17\frac{1}{4}$ reflector is not sufficient really to deal with them satisfactorily.

		1855.		
(1)	Südl. D.M. – 12°·1092	α = V. 4 36·9	δ – 12° 1·8	Mag. 6·5
(2)	D.M. + 39°·3476	XVIII. 33 19·2	+ 39° 32·8	„ 6·5
(3)	D.M. + 49°·2999	XIX. 20 44·2	+ 49° 57·0	„ 7·5

No. 1 was observed on October 30, 1888, only. The spectrum strongly resembles that of *Mira*.

No. 2 was observed on several nights; on two the bright lines were thought doubtful, on one pretty certain.

No. 3.—Observed on several nights, and on each occasion the bright lines suspected.

Height of a Perseid Fireball. By W. F. Denning.

On August 13, 1888, at $11^h\ 33^m$, while watching for shooting stars, I saw a large fireball low in the northern sky. In the earlier part of its flight its magnitude was not considerable, but towards the end it suddenly blazed up with intense brilliancy, and illuminated the whole hemisphere with a flash like lightning. In the brighter part of its path a streak was left, and this remained perceptible about forty seconds. I carefully registered the visible arc of the meteor's course as follows: $113^\circ+57\frac{1}{2}^\circ$ to $126^\circ+52\frac{1}{2}^\circ$. This position lies between the constellations of *Ursa Major* and the *Lynx*, in a region comparatively bare of conspicuous stars.

Mr. David Booth at Leeds partially observed the phenomenon. He was looking towards the north-eastern sky for late Perseids when he was startled by a brilliant flash, which he immediately attributed to vivid lightning, but, on quickly turning round to the west, he noticed a very bright meteor streak projected amongst the stars of *Draco*. Its terminal points were $275^\circ+67^\circ$ and $260^\circ+53^\circ$, and he correctly assumed it to have been left by a fine Perseid. Though straight at first the streak soon became irregularly bent, and after a gradual decadence, occupying three minutes, it finally disappeared.

Mr. Monck at Dublin also saw the same meteor, and approximately noted its flight as from the direction of β *Persei* to 41 *Arietis*; but there were many clouds about in the region of its appearance, which rendered the observation a little uncertain.

He describes the fireball as exceptionally bright, and noticed the decided flash near its extinction.

Several observers at Birmingham and other places have furnished accounts of this object, but only in general terms, and they do not supply any precise data that may be employed in determining the fireball's real path in the atmosphere.

Mr. R. Parke Buckley, of Birmingham, writing on August 14, says, "I witnessed a most extraordinary occurrence in the sky at 11.30 last night. By the stars called Charles's Wain a comet, looking in the sky about 6 feet long by 2 feet, flashed suddenly on the stars forming the square part of the waggon, and lasted for about three minutes, gradually dying away." Mr. H. Basnett, of the same city, says that at 11.30 P.M. he saw what he thought was lightning, but it lasted too long. Everything around he could see quite plainly, as if it were daytime. Looking up at the sky, he noticed a long line of fire, and this lasted quite three minutes.

At Leeds and Bristol the enduring streak enabled the direction of the fireball's flight to be recorded with great precision; and when these observations are compared together they show a very satisfactory accordance. The radiant is indicated at $43^\circ + 56^\circ$, near η *Persei*. This point was in azimuth N. 49° E., altitude 42° at the time of observation. At Bristol the streak extended from $121^\circ + 54\frac{3}{4}^\circ$ to $126^\circ + 52\frac{1}{2}^\circ$; and combining this with its apparent place as noted at Leeds, I find it was suspended vertically over Yorkshire at heights ranging from 59 miles (above a point two miles south of Grassington) to 47 miles (above Gisburn). Its length was 18 miles. But the nucleus of the fireball became visibly incandescent at a much earlier period of its flight through the air than that intimated by the streak, which simply marked the section of its course where it attained its highest degree of combustion and where its material became dissipated. When first seen at Bristol in $113^\circ + 57\frac{1}{2}^\circ$ the meteor was situated above a point three miles north-east of Masham, in the North Riding of Yorkshire, and here it had an elevation of 78 miles. The whole observed path shows therefore a descent from 78 to 47 miles, as follows:

When first observed at Bristol	78 miles high
Beginning of light streak (Leeds and Bristol) ...	59 „ „
End of meteor and light streak (Leeds and Bristol)	47 „ „
Entire length of observed real path (Bristol) ...	46 „ „
Inclination to horizon (Leeds and Bristol) ...	42 degrees

The observation at Dublin, if included, would somewhat increase these heights, but the conditions prevailing there were unfavourable. The materials derived from Leeds and Bristol mutually corroborate the assigned path very closely, and they are sufficient for the present purpose.

Path and Heights of a Perseid Fireball, 1888, August 13, 11ʰ 33ᵐ (W. F. D.).

This meteor was evidently typical of the large fireballs occasionally discharged by this well-known system. The radiant at $43°+56°$ is slightly erratic for the date. On the same night (August 13, 1888) the Perseid radiant was independently determined, from other meteors seen by myself, at $52°+57°$, and by Mr. Booth at $51\frac{1}{2}°+56°$. On August 13, 1885, I found it at $51°+58°$, and on August 13, 1880, at $49\frac{1}{2}°+57\frac{1}{2}°$. The mean of all these is at $51°+57°$, which is $4°$ east of the fireball radiant. The difference is not large, but it can scarcely be accounted for by errors of observation, as they are likely to have been almost nil. The fireball itself was probably discordant to the extent referred to, for the Perseid radiant was not nearly as well defined as usual this year. There appear to be annual variations, not only in the richness of the display, but in the character of its radiation. In some years it is very precise, in others its diffusion is equally marked.

Bristol: 1888, *October* 15.

A Table of the Positions of Observatories, with Constants useful in Correcting Extra-Meridian Observations for Parallax. By Lieut.-General Tennant, R.E., F.R.S.

The discontinuance of old Observatories and the formation of new ones renders the occasional revision of such tables as the present one desirable. The extension of the electric telegraph has facilitated the determination of longitudes, so that the results recently published may be considered practically perfect as regards both elements of position: I hope therefore that the places I now give may require, except in one or two cases, little amendment.

Starting with Mr. Lancaster's "Liste Générale," I have omitted some Observatories which never should have been admitted as astronomical establishments, such as Calcutta and Bombay. Then I have examined the positions with the *Berliner Jahrbuch*, *Connaissances des Temps*, *Nautical Almanac*, and *American Nautical Almanac*, preferring each authority for the places of its own nation. A few corrections have been made from the *Monthly Notices* and other sources, and some new Observatories have been added, as well as some omitted, which I had no reason to suppose were very active. For the places of Mr. Brooks's new Observatory (Smith Observatory) at Geneva I am indebted to that gentleman. But I have not been able to get the position of the new Dearborn Observatory, and we now hear that the establishment at Edinburgh is to be moved, but it is useless to wait till changes cease.

In computing the constants I have used Col. Ross Clarke's figure of the Earth, which is certainly the best known, and I have used 8″·78 for the Mean Solar Parallax. The table is otherwise only a recomputation and slight extension of the corresponding one in Oppolzer's *Lehrbuch*, vol. i. The figure of the Earth makes but slight changes, but it is otherwise with the Solar Parallax. The value I have taken is a very small one, so that a constant addition to the last three logarithms will correct to any value likely to be preferred: Newcomb's parallax requires an addition of 0·0034.

The formulæ I have used are Oppolzer's:

$$\tan\phi_1 = \frac{b}{a}\tan\phi : \tan\phi' = \frac{b}{a}\tan\phi_1 ; \ \log\frac{a}{b} = 9{\cdot}9985176,$$

$$A = \frac{\pi}{15}\cos\phi_1 ; \ D = \pi . \frac{b}{a}\sin\phi_1 ;$$

and I have added

$$P = \pi . \frac{\cos\phi_1}{\cos\phi'}, \ \cancel{= A\pi \text{ of Oppolzer}},$$

which is used to correct the solar places in computing orbits.

If θ be the Sidereal Time, α and δ the true, and α' and δ' the observed, Right Ascensions and Declinations, then

$$\tan\gamma = \frac{\tan\phi'}{\cos(\theta-\alpha')}\,;\quad \alpha-\alpha' = \frac{A}{\rho}\,\frac{\sin(\theta-\alpha')}{\cos\delta'}\,;\quad \delta-\delta' = \frac{D}{\rho}\,\frac{\sin(\gamma-\delta')}{\sin\gamma}.$$

A practice has arisen (largely followed in the United States) of calling an observatory after some person whom it is desired to commemorate. The result is not always convenient. I have however generally used these names in the following table, and add a list of synonyms for the purpose of further identifying places of observation.

The Observatory at Albany	is Dudley Observatory.
" " Amherst	" Lawrence "
" of Michigan University	" Ann Arbor "
" at Cambridge, U.S.	" Harvard Coll. "
" " Chicago	" Dearborn "
" " Clinton, N.Y.	" Litchfield "
" " Glasgow (Miss.)	" Morrison "
" " Evanston Isle	" New Dearborn "
The Dartmouth Observatory	" at Hanover.
The Observatory at Madison (Wis.)	" Washburn Observatory.
" " Mount Hamilton	" Lick "
" " New Haven	" Winchester "
" of Columbia College	" at New York.
" at Northfield	" Carleton Coll. "
The Radcliffe Observatory	" at Oxford.
" Vassar College Observatory	" at Poughkeepsie.
The Observatory at Richmond (Virg.)	" Leander McCormick Observatory.
" " Rochester	" Warner Observatory.
" " South Bethlehem	" Sayre "
" of Vanderbilt University	is at Nashville.

P.S.—I have thought it best to give the new place of Dearborn Observatory from Keith Johnston's place of Evanston, correcting for error of longitude of Chicago. It will serve better for reducing observations than the old value, though it is not accurate.

Positions of Observatories and Constants for Parallaxes.

Names.	Longitudes from Greenwich. Time.	Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan φ′.	Constants. log A.	log D.	log P.	
	h m s	d	s	° ′ ″					
Adelaide	+ 9 14 21·3	+0·384969	−91·06	−34 35 34	9·8411$_n$	9·6816	0·6987$_n$	0·9430	
Alfred Centre	− 5 11 07·0	−0·216053	+51·11	+42 15 20	9·9554	9·6374	0·7688	0·9428	
Algiers	+ 0 12 16·9	+0·008529	− 2·02	+36 44 00	9·8699	9·6718	0·7178	0·9430	
Allegheny	− 5 20 02·9	−0·222256	+52·58	+40 27 42	9·9279	9·6493	0·7533	0·9429	
Annapolis	− 5 05 56·4	−0·212458	+50·26	+38 58 54	9·9051	9·6586	0·7398	0·9429	Naval Acad.
Ann Arbor (Mich.) ...	− 5 34 55·1	−0·232582	+55·02	+42 16 48	9·9557	9·6372	0·7690	0·9428	Near Detroit
Antwerp	+ 0 17 38·6	+0·012252	− 2·90	+51 12 28	0·0919	9·5652	0·8332	0·9426	A. de Boë
Arcetri	+ 0 45 03·1	+0·031286	− 7·40	+43 45 14	9·9781	9·6268	0·7811	0·9428	Near Florence
Armagh	− 0 26 35·5	−0·018466	+ 4·37	+54 21 13	0·1414	9·5339	0·8514	0·9424	
Athens	+ 1 34 54·9	+0·065913	−15·59	+37 58 20	9·8894	9·6647	0·7302	0·9429	
Beloit Coll. (Wis.) ...	− 5 56 07·3	−0·247307	+58·50	+42 30 09	9·9591	9·6357	0·7709	0·9428	Smith Observatory
Bergen	+ 0 21 13·0	+0·014734	− 3·49	+60 23 54	0·2426	9·4622	0·8809	0·9424	
Berlin	+ 0 53 34·9	+0·037210	− 8·80	+52 30 17	0·1121	9·5527	0·8409	0·9426	
Berne	+ 0 29 45·7	+0·020667	− 4·89	+46 57 09	0·0267	9·6024	0·8051	0·9427	
Besançon	+ 0 23 57·2	+0·016634	− 3·93	+47 14 59	0·0312	9·5999	0·8072	0·9427	
Bilk	+ 0 27 05·0	+0·018808	− 4·45	+51 12 25	0·0919	9·5652	0·8332	0·9426	Near Düsseldorf
Birr Castle	− 0 31 40·9	−0·022001	+ 5·20	+53 05 47	0·1214	9·5468	0·8444	0·9425	Lord Rosse
Bologna	+ 0 45 24·9	+0·031538	− 7·46	+44 29 47	9·9894	9·6214	0·7869	0·9428	
Bonn	+ 0 28 23·3	+0·019714	− 4·66	+50 43 45	0·0845	9·5697	0·8302	0·9426	

Names.	Longitudes from Greenwich. Time.	Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan ϕ'.	Constants. log A.	log D.	log P.	
	h m s	d	s	° ′ ″					
Bordeaux...	− 0 02 05·4	−0·001451	+ 0·35	+44 50 07	9·9945	9·6189	0·7895	0·9428	
Bothkamp	+ 0 40 31·2	+0·028197	− 6·66	+54 12 10	0·1390	9·5355	0·8506	0·9425	Baron von Bülow
Breslau	+ 1 08 08·9	+0·047325	−11·20	+51 06 57	0·0905	9·5661	0·8326	0·9426	
Brussels	+ 0 17 28·7	+0·012138	− 2·87	+50 51 11	0·0864	9·5685	0·8310	0·9426	
Buda Pesth	+ 1 16 15·4	+0·052956	−12·53	+47 29 35	0·0349	9·5979	0·8089	0·9427	Also Ofen
Cambridge	+ 0 00 22·8	+0·000264	− 0·06	+52 12 52	0·1076	9·5556	0·8392	0·9426	
Cape of Good Hope ...	+ 1 13 54·7	+0·051328	−12·14	−33 56 03	9·8249$_n$	9·6968	0·6878$_n$	0·4930	
Carleton College... ...	− 6 12 36	−0·258750	+61·21	+44 27 41	9·9889	9·6217	0·7866	0·9428	Northfield (Min.)
Carlsruhe	+ 0 33 36·5	+0·023339	− 5·52	+49 00 30	0·0580	9·5851	0·8192	0·9426	
Chabot	− 8 00 06·3	−0·333406	+78·87	+37 48 05	9·8867	9·6657	0·7285	0·9429	California Univ.
Chapultepec	− 6 36 38·2	−0·275442	+65·16	+19 25 18	9·5443	9·7420	0·4624	0·9432	Near Mexico
Christiania	+ 0 42 53·8	+0·029789	− 7·05	+59 54 44	0·2341	9·4686	0·8788	0·9424	
Cincinnati	− 5 37 41·3	−0·234506	+55·47	+39 08 20	9·9076	9·6576	0·7413	0·9429	
Coimbra	− 0 33 34·1	−0·023311	+ 5·51	+40 12 26	9·9240	9·6509	0·7511	0·9429	
Cologne	+ 0 27 51	+0·019340	− 4·58	+50 55 31	0·0875	9·5679	0·8315	0·9426	Dr. Klein
Copenhagen	+ 0 50 18·9	+0·034941	− 8·27	+55 41 13	0·1629	9·5195	0·8585	0·9425	
Cordoba	− 4 16 48·2	−0·178336	+42·19	−31 25 15	9·7830$_n$	9·6989	0·6580$_n$	0·9431	
Cracow	+ 1 19 50·4	+0·055444	−13·11	+50 03 50	0·0742	9·5758	0·8261	0·9426	
Dantzig	+ 1 14 39·6	+0·051847	−12·16	+54 21 18	0·1414	9·5339	0·8514	0·9425	
Dearborn (Old)	− 5 50 27·1	−0·243369	+57·57	+41 50 01	9·9489	9·6403	0·7653	0·9428	Chicago (U.S.)

Names.	Longitudes from Greenwich. Time.	Longitudes from Greenwich. Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan ϕ'.	Constants. log A.	Constants. log D.	log P.	
	h m s	d	s	° ′ ″					
Dearborn (New) ...	− 5 51 00	− 0·243750	+ 57·66	+ 42 05	9·9527	9·6386	0·7674	0·9428	Evanston (Ill.)
Dorpat	+ 1 46 53·6	+ 0·074231	− 17·56	+ 58 22 47	0·2077	9·4880	0·8718	0·9424	
Dresden	+ 0 54 54·8	+ 0·038134	− 9·02	+ 51 02 17	0·0893	9·5668	0·8322	0·9426	Baron v. Englehardt
Dublin	− 0 25 22	− 0·017616	+ 4·16	+ 53 23 13	0·1260	9·5439	0·8460	0·9425	Dunsink
Dudley	− 4 54 59·7	− 0·204858	+ 48·46	+ 42 39 50	9·9616	9·6346	0·7722	0·9428	Albany (N.Y.)
Dunecht	− 0 09 40·0	− 0·006713	+ 1·59	+ 57 09 36	0·1872	9·5027	0·8660	0·9424	Lord Crawford
Durham	− 0 06 19·8	− 0·004396	+ 1·04	+ 54 46 06	0·1481	9·5295	0·8536	0·9424	
Ealing	− 0 01 13	− 0·000845	+ 0·20	+ 51 31 07	0·0967	9·5623	0·8351	0·9426	A. A. Common
Edinburgh	− 0 12 43·6	− 0·008826	+ 2·09	+ 55 57 23	0·1673	9·5165	0·8599	0·9425	
Florence	+ 0 45 01·9	+ 0·031272	− 7·40	+ 43 46 04	9·9783	9·6267	0·7812	0·9428	Museum
Frankfurt	+ 0 34 47·1	+ 0·024156	− 5·71	+ 50 07 03	0·0750	9·5753	0·8264	0·9426	Dr. Epstein
Geneva	+ 0 24 36·8	+ 0·017093	− 4·04	+ 46 11 59	0·0152	9·6084	0·7997	0·9427	
Genoa	+ 0 35 41·4	+ 0·027525	− 5·86	+ 44 25 09	9·9882	9·6220	0·7863	0·9428	Naval Obs.
Georgetown (D.C.) ...	− 5 08 18·2	− 0·214101	+ 50·65	+ 38 54 26	9·9040	9·6590	0·7391	0·9429	
Glasgow	− 0 17 10·6	− 0·011928	+ 2·82	+ 55 52 43	0·1661	9·5173	0·8595	0·9425	
Göhlis	+ 0 49 29·6	+ 0·034370	− 8·13	+ 51 21 35	0·0942	9·5638	0·8341	0·9426	Herr Winkler
Gotha	+ 0 42 50·6	+ 0·029752	− 7·04	+ 50 56 38	0·0878	9·5677	0·8316	0·9426	
Göttingen	+ 0 39 46·4	+ 0·027620	− 6·53	+ 51 31 48	0·0969	9·5622	0·8352	0·9426	
Grätz	+ 1 01 47·9	+ 0·042916	− 10·15	+ 47 04 37	0·0285	9·6013	0·8060	0·9427	
Greenwich	0 00 00·0	0·000000	0·00	+ 51 28 38	0·0961	9·5627	0·8348	0·9426	

Names.	Longitudes from Greenwich. Time.	Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan φ′.	Constants. log A.	log D.	log P.	
	h m s	d	s	° ′ ″					
Grignon	+ 0 17 37·9	+0·012244	− 2·90	+47 33 42	0·0359	9·5974	0·8094	0·9427	
Halifax	− 0 07 28	−0·005185	+ 1·23	+53 42 09	0·1310	9·5407	0·8478	0·9425	E. Crossley
Hamburg	+ 0 39 53·8	+0·027706	− 6·55	+53 33 07	0·1287	9·5422	0·8470	0·9425	
Hanover (N.H.)	− 4 49 08·0	−0·200787	+47·50	+43 42 15	9·9774	9·6272	0·7807	0·9428	
Harrow (Hill Foot) ...	− 0 01 19·9	−0·000925	+ 0·22	+51 34 47	0·0977	9·5617	0·8355	0·9426	Col. Tupman
Harvard Coll. Obs. ...	− 4 44 31·0	−0·197581	+46·74	+42 22 48	9·9573	9·6365	0·7699	0·9428	Cambridge (Mass.)
Haverford (N.J.)(Coll.Obs.)	− 5 01 12·7	−0·209175	+49·48	+40 00 40	9·9210	9·6522	0·7493	0·9429	
Heidelberg	+ 0 34 48·5	+0·024172	− 5·72	+49 24 35	0·0642	9·5816	0·8218	0·9426	
Helsingfors	+ 1 39 49·2	+0·069319	−16·39	+60 09 43	0·2384	9·4653	0·8799	0·9424	
Herény	+ 1 06 24·7	+0·046119	−10·91	+47 15 47	0·0314	9·5998	0·8073	0·9427	Von Gothard
Hudson	− 5 25 44·2	−0·226206	+53·51	+41 14 43	9·9400	9·6442	0·7602	0·9428	
Juvisy	+ 0 09 29	+0·006586	− 1·56	+48 41 36	0·0532	9·5878	0·8171	0·9427	C. Flammarion
Kalocsa	+ 1 15 55·7	+0·052728	−12·47	+46 31 41	0·0202	9·6058	0·8021	0·9427	Card. Haynald
Kasan	+ 3 16 29·1	+0·136448	−32·28	+55 47 24	0·1646	9·5183	0·8590	0·9425	
Kempshott (Jam.) ...	− 5 11 10	−0·216088	+51·12	+18 24 51	9·5194	9·7447	0·4402	0·9433	M. Hall
Kharkoff...	+ 2 24 54·7	+0·100633	−23·80	+50 00 10	0·0733	9·5763	0·8257	0·9426	
Kieff	+ 2 02 00·7	+0·084730	−20·04	+50 27 11	0·0802	9·5722	0·8285	0·9426	
Kiel	+ 0 40 35·7	+0·028191	− 6·67	+54 20 29	0·1412	9·5340	0·8513	0·9425	
Königsberg	+ 1 21 59·1	+0·056934	−13·47	+54 42 51	0·1472	9·5301	0·8533	0·9425	

Names.	Longitudes from Greenwich. Time.	Longitudes from Greenwich. Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan φ′.	Constants. log A.	Constants. log D.	log P.	
	h m s	d	s	° ′ ″					
Kremsmunster	+ 0 56 31·6	+0·039255	− 9·29	+48 03 24	0·0435	9·5932	0·8128	0·9427	
Kuffner Obs.	+ 1 05 11·1	+0·045267	−10·71	+48 12 48	0·0459	9·5919	0·8139	0·9427	Ottakring (Vienna)
La Plata	− 3 51 37	−0·161539	+39·59	−34 54 30	9·8408$_n$	9·6817	0·6986$_n$	0·9430	
Launceston (Tasm.) ...	+ 9 48 31	+0·408692	−96·68	−41 26 01	9·9428$_n$	9·6429	0·7619$_n$	0·9428	A. B. Biggs
Lawrence Obs.	− 4 50 04·7	−0·201443	+47·65	+42 22 17	9·9571	9·6366	0·7698	0·9428	Amherst (Mass.)
Leander McCormick Obs.	− 5 14 00·7	−0·218064	+51·58	+38 02 01	9·8904	9·6643	0·7308	0·9429	Richmond (Vir.)
Leiden	+ 0 17 56·4	+0·012458	− 2·95	+52 09 20	0·1067	9·5561	0·8389	0·9426	
Leipzig	+ 0 49 34·0	+0·034422	− 8·14	+51 20 06	0·0939	9·5640	0·8340	0·9426	University Obs.*
Lick	− 8 06 34·1	−0·337895	+79·93	+37 20 23	9·8795	9·6684	0·7240	0·9430	Mt. Hamilton (Cal.)
Lisbon	− 0 36 44·7	−0·025518	+ 6·04	+38 42 31	9·9009	9·6603	0·7372	0·9429	
Litchfield Obs.	− 5 01 37·4	−0·209461	+49·55	+43 03 17	9·9675	9·6318	0·7754	0·9428	Clinton (N.Y.)
Louvain	+ 0 18 51·0	+0·013090	− 3·09	+50 52 40	0·0868	9·5683	0·8312	0·9426	Dr. Terby
Lübeck	+ 0 42 45·7	+0·029696	− 7·02	+53 51 31	0·1335	9·5391	0·8487	0·9425	
Lund	+ 0 52 45·0	+0·036632	− 8·67	+55 41 52	0·1631	9·5193	0·8586	0·9425	
Lyons	+ 0 19 07·9	+0·013286	− 3·14	+45 41 40	0·0076	9·6123	0·7960	0·9427	
Madras	+ 5 20 59·3	+0·222910	−52·73	+13 04 08	9·3628	9·7561	0·2949	0·9434	
Madrid	− 0 14 45·1	−0·010244	+ 2·42	+40 24 30	9·9271	9·6497	0·7529	0·9429	

* Same quantities for Dr. Engelmann's Observatory.

Names.	Longitudes from Greenwich. Time.	Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan φ′.	Constants. log A.	log D.	log P.	
	h m s	d	s	° ′ ″					
Markree	− 0 33 48·4	−0·023477	+ 5·55	+54 10 32	0·1386	9·5358	0·8504	0·9425	Col. Cooper
Marseilles	+ 0 21 34·6	+0·014984	− 3·54	+43 18 19	9·9713	9·6290	0·7775	0·9428	
Melbourne	+ 9 39 53·4	+0·402701	−95·26	−37 49 53	9·8872n	9·6655	0·7288n	0·9429	
Mexico	− 6 36 26·6	−0·275308	+65·13	+19 26 01	9·5446	9·7421	0·4628	0·9433	
Milan	+ 0 36 46·0	+0·025532	− 6·04	+45 27 59	0·0041	9·6141	0·7943	0·9427	
Modena	+ 0 43 42·9	+0·030358	− 7·18	+44 38 53	9·9917	9·6203	0·7881	0·9428	
Moncalieri	+ 0 30 49	+0·021399	− 5·06	+44 59 51	9·9970	9·6176	0·7907	0·9427	Near Turin
Morrison Obs.	− 6 11 18·0	−0·257847	+61·00	+39 13 46	9·9090	9·6571	0·7421	0·9429	Glasgow (Miss.)
Moscow	+ 2 30 17·2	+0·104366	−24·69	+55 45 20	0·1641	9·5187	0·8589	9·9425	
Munich	+ 0 46 26·1	+0·032247	− 7·63	+48 08 45	0·0448	9·5925	0·8134	0·9427	
Naples	+ 0 57 00·5	+0·039589	− 9·36	+40 51 45	9·9341	9·6467	0·7569	0·9429	Capo di Monte
Nashville (Tenn.) ...	− 5 47 08·0	−0·241065	+57·03	+36 08 58	9·8607	9·6750	0·7118	0·9430	Vanderbilt Univ.
Natal	+ 2 02 01·2	+0·084736	−20·04	−29 50 47	9·7558n	9·7060	0·6378n	0·9431	
Neuchatel	+ 0 27 49·9	+0·019328	− 4·57	+47 00 01	0·0274	9·6020	0·8054	0·9427	
New York (Col. Coll.) ...	− 4 55 53·6	−0·205481	+48·61	+40 45 23	9·9325	9·6474	0·7560	0·9429	
„ (Ruth.) ...	− 4 55 57·0	−0·205520	+48·62	+40 43 48	9·9321	9·6476	0·7557	0·9429	L. Rutherford
Nice	+ 0 29 12·3	+0·020281	− 4·80	+43 43 17	9·9776	9·6271	0·7808	0·9428	Montgros
Nicolaieff	+ 2 07 53·9	+0·088818	−21·01	+46 58 21	0·0270	9·6022	0·8052	0·9427	
Odessa	+ 2 03 02·4	+0·085444	−20·21	+46 28 36	0·0194	9·6062	0·8017	0·9427	

Names.	Longitudes from Greenwich. Time.	Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan φ'.	Constants. log A.	log D.	log P.	
	h m s	d	s	° ′ ″					
O'Gyalla	+ 1 12 45·6	+0·050528	−11·95	+47 52 27	0·0407	9·5948	0·8115	0·9427	Dr. von Konkoly
Orwell Park	+ 0 04 55·8	+0·003424	− 0·81	+52 00 33	0·1044	9·5576	0·8380	0·9426	Col. Tomline
Ougrée	+ 0 22 12	+0·015417	− 3·65	+50 37 06	0·0828	9·5707	0·8296	0·9426	Near Liège
Oxford (Radcliffe Obs.)...	− 0 05 02·6	−0·003502	+ 0·83	+51 45 36	0·1005	9·5600	0·8365	0·9426	
„ (University Obs.)	− 0 05 00·4	−0·003477	+ 0·82	+51 45 34					
„ (Mississippi) ...	− 5 58 07·1	−0·248693	+58·83	+34 22 13	9·8321	9·6845	0·6927	0·9430	
Padua	+ 0 47 29·2	+0·032977	− 7·80	+45 24 02	0·0031	9·6146	0·7938	0·9426	
Palermo	+ 0 53 24·7	+0·037091	− 8·77	+38 06 44	9·8916	9·6638	0·7315	0·9429	
Paris	+ 0 09 21·0	+0·006492	− 1·54	+48 50 11	0·0554	9·5866	0·8181	0·9426	
Philadelphia	− 5 00 38·5	−0·208779	+49·39	+39 57 07	9·9201	9·6526	0·7488	0·9429	
Plonsk	+ 1 21 32	+0·056620	−13·39	+52 37 39	0·1141	9·5515	0·8417	0·9426	Dr. Jedrzejewicz
Pola	+ 0 55 23·2	+0·038463	− 9·10	+44 51 49	9·9950	9·6186	0·7897	0·9427	
Potsdam	+ 0 52 15·9	+0·036295	− 8·58	+52 22 55	0·1102	9·5539	0·8402	0·9426	
Poughkeepsie (N.Y.) ...	− 4 55 33·6	−0·205250	+48·55	+41 41 18	9·9467	9·6412	0·7640	0·9428	
Poulkova	+ 2 01 18·6	+0·084243	−19·93	+59 46 19	0·2316	9·4705	0·8782	0·9422	
Prague	0 57 41·5	+0·040064	− 9·48	+50 05 18	0·0746	9·5755	0·8262	0·9426	I.R. Observatory
„	0 5 47	+0·040127	− 9·49	+50 04 25	0·0744	9·5757	0·8261	0·9426	Prof. Safarik
Princeton (N.J.) ...	− 4 58 37·5	−0·207378	+49·06	+40 20 58	9·9262	9·6500	0·7523	0·9429	
Providence (R.I.) ...	− 4 45 37·6	−0·198352	+46·92	+41 49 46	9·9489	9·6403	0·7653	0·9428	F. E. Seagrave

Names.		Longitudes from Greenwich. Time.	Parts of Day.	Correction to S.T.M.N.	Latitudes.	tan φ.	Constants. log A.	log D.	log P.	
		h m s	d	s	° ′ ″					
Puebla (Mexico)...	...	− 6 32 41	−0·272697	+64·50	+19 02 30	9·5350	9·7431	0·4542	0·9433	
Rio de Janeiro ...	...	− 2 52 41·4	−0·119924	+28·37	−22 54 24	9·6229$_n$	9·7319	0·5310$_n$	0·9433	
Rome (Coll. Rom.)	...	+ 0 49 55·5	+0·034670	− 8·20	+41 53 54	9·9499	9·6398	0·7658	0·9428	
„ (Capitol) ...	...	+ 0 49 56·5	+0·034682	− 8·20	+41 53 33	9·9498	9·6399	0·7658	0·9428	
St. Louis (Miss.)	...	− 6 00 49·1	−0·250568	+59·27	+38 38 04	9·8997	9·6607	0·7365	0·9429	
St. Petersburg ...	...	+ 2 01 11·4	+0·084160	−19·91	+59 56 32	0·2346	9·4682	0·8789	0·9424	University
San Fernando ...	...	− 0 24 49·2	−0·017136	+ 4·08	+36 27 41	9·8656	9·6733	0·7150	0·9430	
San Francisco (Cal.)	...	− 8 09 42·5	−0·340075	+80·46	+37 47 24	9·8866	9·6657	0·7284	0·9429	G. Davidson
Santiago (Chili)	...	− 4 42 46·3	−0·196369	+46·45	−33 26 42	9·8169	9·6892	0·6822	0·9430	
Sayre Observatory	...	− 5 01 31·9	−0·209397	+49·53	+40 36 24	9·9302	9·6484	0·7546	0·9429	S. Bethlehem
Scarborough ...	...	− 0 01 38·9	−0·001145	+ 0·27	+54 16 30	0·1402	9·5347	0·8510	0·9425	R. Wigglesworth
Smith Obs., Geneva (N.Y.)		− 5 08 00	−0·213889	+50·60	+42 53 00	9·9649	9·6330	0·7740	0·9427	W. R. Brooks
South Hadley ...	...	− 4 50 20·3	−0·201624	+47·70	+42 15 18	9·9554	9·6374	0·7688	0·9428	
Stockholm ...	...	+ 1 12 14·0	+0·050162	−11·87	+59 20 34	0·2242	9·4760	0·8762	0·9424	
Stonyhurst ...	...	− 0 09 52·7	−0·006860	+ 1·62	+53 50 40	0·1333	9·5392	0·8486	0·9425	
Strasburg ...	...	+ 0 31 04·7	+0·021582	− 5·11	+48 35 00	0·0515	9·5888	0·8164	0·9428	
Sydney (N.S.W.)	...	+10 04 48·5	+0·420006	−99·35	−33 51 41	9·8238$_n$	9·6871	0·6870$_n$	0·9430	
Tacubaya ...	...	− 6 36 46·5	−0·275538	+65·18	+19 24 17	9·5439	9·7422	0·4621	0·9433	
Tashkent... ...	...	+ 4 37 10·8	+0·192486	−45·54	+41 19 32	9·9412	9·6437	0·7609	0·9428	

Names.	Longitudes from Greenwich. Time. h m s	Parts of Day. d	Correction to S.T.M.N. s	Latitudes. ° ′ ″	tan φ′.	Constants. log A.	log D.	log P.	
Toulouse	+ 0 05 51·0	+0·004063	− 0·96	+43 36 45	9·9760	9·6279	0·7799	0·9428	
Trieste	+ 0 55 02·1	+0·038219	− 9·04	+45 38 34	0·0068	9·6127	0·7956	0·9427	
Tulse Hill	− 0 00 27·7	−0·000321	+ 0·08	+51 26 47	0·0956	9·5630	0·8346	0·9426	Dr. W. Huggins
Turin	+ 0 30 47·2	+0·021380	− 5·06	+45 04 08	9·9981	9·6171	0·7913	0·9427	
Upsala	+ 1 10 30·2	+0·048961	−11·58	+59 51 29	0·2331	9·4693	0·8785	0·9424	
Urbino	+ 0 50 33·1	+0·035105	− 8·30	+43 43 30	9·9777	9·6270	0·7808	0·9428	
Utrecht	+ 0 20 31·7	+0·014256	− 3·37	+52 05 09	0·1056	9·5568	0·8385	0·9426	
Venice	+ 0 49 25·8	+0·034326	− 8·12	+45 25 49	0·0036	9·6143	0·7940	0·9427	
Vienna	+ 1 05 21·5	+0·045388	−10·74	+48 13 55	0·0461	9·5918	0·8140	0·9427	Imp. Obs.
Warner Observatory ...	− 5 10 21·8	−0·215530	+50·99	+43 09 17	9·9690	9·6311	0·7763	0·9482	Rochester, N.Y.
Warsaw	+ 1 24 07·3	+0·058418	−13·82	+52 13 06	0·1076	9·5555	0·8393	0·9426	
Washburn Observatory ...	− 5 57 36·2	−0·248355	+58·75	+43 04 37	9·9679	9·6317	0·7756	0·9428	Madison (Wis.)
Washington	− 5 08 12·0	−0·214028	+50·63	+38 53 39	9·9038	9·6591	0·7390	0·9429	
Wilhelmshaven	+ 0 32 35·2	+0·022630	− 5·35	+53 31 52	0·1283	9·5424	0·8468	0·9425	
Williamstown (Mass.) ...	− 4 52 53·4	−0·203396	+48·11	+42 42 49	9·9623	9·6342	0·7726	0·9428	
Wilna	+ 1 41 09·0	+0·070243	−16·62	+54 40 59	0·1467	9·5304	0·8532	0·9425	
Winchester Observatory	− 4 51 42·1	−0·202571	+47·92	+41 18 37	9·9409	9·6438	0·7608	0·9428	New Haven (Conn.)
Windsor (N.S.W.) ...	+10 03 19·2	+0·418972	−99·11	−33 36 31	9·8196$_n$	9·6884	0·6841$_n$	0·9430	J. Tebbutt
Zürich	+ 0 34 12·4	+0·023755	− 5·62	+47 22 40	0·0331	9·5989	0·8081	0·9427	

Observations of Comet a 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following observations of Comet Sawerthal were made with the Barclay equatorial, using the ring-micrometer, with power 100. On account of the faintness of the comet the observations were very difficult, and the probable errors of the results must therefore be regarded as much larger than those of the earlier series.

1888.		Greenwich Mean Time.	Observer.	Comet−Star Δ R.A. (Corrected for Refraction only.)	Comet−Star Δ N.P.D. (Corrected for Refraction only.)	No. of Comps.	Apparent R.A. of Comet.	Log $p\Delta$	Apparent N.P.D. of Comet.	Log $p\Delta$	Comp. Star.
		h m s		m s	′ ″		h m s		° ′ ″		
July	3	11 25 22	W.	−0 15·99	−2 52·07	4	1 3 3·58	9·4065	41 29 53·3	0·4185	1
	5	11 7 27	F. B.	−3 50·00	−5 34·39	5	1 4 9·22	9·4029	41 4 25·6	0·4295	2
	12	11 3 1	R.	+0 15·10	+5 37·53	12	1 7 5·18	9·4196	39 38 56·9	0·3870	3
Aug.	8	12 4 3	W.	−1 2·63	−1 1·62	12	0 59 49·44	9·3798	35 36 50·6	9·8646	4

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent Place.	Mean N.P.D. 1888·0.	Reduction to Apparent Place.	Authority.
	h m s	s	° ′ ″	″	
1	1 3 18·57	+1·00	41 32 34·15	+11·21	Mean of Radcliffe I. 347, Oeltz. Arg. (N.) 1155, and Lalande 2011.
2	1 7 58·17	+1·05	41 9 48·87	+11·11	Mean of Radcliffe I. 379 and Paris 1566.
3	1 6 48·70	+1·38	39 33 8·96	+10·38	Oeltz. Arg. (N.) 1236.
4	1 0 49·18	+2·89	35 37 46·08	+ 6·18	Mean of Radcliffe I. 329 and Greenwich (1872) 103, adopting proper motions of $+0^s{\cdot}386$ in R.A., and $+1''{\cdot}56$ in N.P.D.

Observers' Remarks.

1888, July 3.—Clouds keep passing. Tail estimated at 8′ in length, but nucleus only glimmers out now and then; end of luminosity observed. The "wing" appendages seen on May 23 have disappeared.

July 5.—Nucleus showed up at times, and was then as bright as an 11th magnitude star. The nucleus was observed when visible. Clouds were continually passing.

July 12.—The nucleus exceedingly faint, and only seen occasionally. Observations very difficult.

August 8.—Night exceptionally fine. When the eye became accustomed to the field, which was rich with small stars, the comet could be distinguished as very faint luminous haze. Occasionally a coma showed itself as a brightening near the head of the luminosity.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

Radcliffe Observatory, Oxford:
1888, *November* 8.

Observations of Comet e 1888 (Barnard), made at Stonyhurst College Observatory. By the Rev. W. J. Crofton, S.J., B.A.

(*Communicated by the Rev. S. J. Perry.*)

1888.	Stonyhurst Mean Time.	✱–☄ R.A.	✱–☄ N.P.D.	No. of Comps.	Comp. Star.
	h m s	s	′ ″		
Oct. 12	16 6 29	+37·71	−13 29·0	10	*a*
„ 13	15 28 20	− 0·60	− 9 54·0	9	*b*

Mean Places of Comparison Stars.

Comp. Star.	R.A. 1888·0.	N.P.D. 1888·0.	Authority.
	h m s	° ′ ″	
a	6 23 46·86	82 46 53·2	Lal. 12434
b	6 21 18·70	82 59 53·4	W.B. VI. 579

Observers: W. J. Crofton and W. Carlisle.

The observations were taken over two bars at right angles and inclined at 45° to the declination circle. The corrections for refraction and parallax have been applied.

The comet presented a starry nucleus (estimated 10–11 mag.), surrounded by a round nebulosity, but without tail. On the 12th, what appeared a 10th mag. star was perceived through the body of the comet, towards the edge. It was not seen on the 13th.

Observations of Jupiter's Satellites made at the Stonyhurst Observatory. By the Rev. S. J. Perry, D.Sc., F.R.S.

	Sat.	Phenomena.	G. M. T. h m s	Corr. to N. A. m s	Observer.	Remarks.
1886, April 11	III.	Tr. Ingress, ext. cont.	9 48 17·3		S. J. P.	
		bisection	9 51 47·6		„	Definition fair.
		int. cont.	9 55 48·8		„	
	III.	Tr. Egress, int. cont.	12 34 50·6		W. C.	
		bisection	12 37 16·1		„	Sky covered with thin clouds.
		ext. cont.	12 40 49·1		„	
29	III.	Occ. Reapp. bisection	9 21 31·8		„	Very unsteady.
		last cont.	0 24 52·3		„	
	III.	Ec. Disapp. ½ light	9 59 23·5		S. J. P.	Good.
		v. faint	10 2 15·8		„	Boiling.
		last seen	10 3 23·3	+4 23·3	„	„
	III.	Ec. Reapp. first seen	12 40 53·4	−0 29·6	W. C.	Good.
		½ light	12 44 56·9		„	Compared with I.
		full light	12 49 6·9		„	
30	IV.	Occ. Reapp. first seen	9 55 26·8		„	
		bisection	10 4 27·8		„	Definition very bad.
		last cont.	10 13 8·9		„	

	Sat.	Phenomena.	G. M. T. h m s	Corr. to N. A. m s	Observer.	Remarks.
May 6	III.	Oc. Reapp. bisection	12 50 43·5		W. C.	
		last cont.	12 55 24·0		„	
	III.	Ec. Disapp. last seen	13 58 16·5	+0 21·5	„	
	III.	Oc. Disapp. first cont.	9 55 3·5		„	
		bisection	9 58 43·5		„	
		last cont.	10 2 30·5		„	
June 5	II.	Ec. Reapp. first seen	12 13 41·5	+0 15·5	„	
		full light	12 17 10		„	
Dec. 28	II.	Oc. Reapp. bisection	17 1 5·8		„	Definition pretty good.
		last. cont.	17 5 4		„	
1887, Jan. 19	III.	Ec. Reapp., first seen	15 16 18·5	−1 35·5	„	Sky hazy.
		½ light	15 20 43·0		„	
		full light	15 24 5·0		„	
March 3	III.	Ec. Disapp., light fading	12 57 20		„	Pretty good.
		½ light	13 1 20		„	
		last seen	13 7 56·9	+3 44·9	„	
	III.	Ec. Reapp., first seen	14 53 39·7	−3 23·2	„	
		½ light	14 58 35		„	
		full light	15 2 52		„	

	Sat.	Phenomena.	G. M. T. h m s	Corr. to N. A. m	Observer.	Remarks.
March 13	I.	Ec. Disapp., fading	11 12 46·5		W. J. C.	
			11 17 15·5		„	Definition poor.
			11 24 38·0	−0 23	„	
May 7	I.	Ec. Reapp., first seen	10 13 7	−0 7	W. C.	
		½ light	10 14 10		„	Definition good.
		full light	10 16 0		„	
	I.	Ec. Reapp., first seen	10 13 24	+ 10	W. J. C.	
1888, Feb. 15	II.	Tr. Egress, last cont.	18 11 8·7		„	Definition poor.
17	III.	Ec. Disapp., last seen	15 54 58	+1 56	W. C.	
		Ec. Reapp., first seen	17 23 32·0	−1 29	„	Unsteady.
		full light	17 29 40		„	
	III.	Ec. Reapp., first seen	17 23 35	−1 27	W. J. C.	
		½ light	17 26 6·5		„	Dancing.
		full light.	17 28 43		„	
May 16	I.	Ec. Disapp., last seen	12 52 59	−0 9	W. C.	Good.
21	II.	Tr. Ingress, ext. cont.	11 57 30		„	
		bisection	11 59 20		„	Definition very bad.
		int. cont.	12 1 42		„	
	II.	Tr. Egress, bisection	14 24 18		„	Definition poor. Un-
		last cont.	14 26 50		„	steady.

	Sat.	Phenomena.	G. M. T. h m s	Corr. to N. A. m s	Observer.	Remarks.
May 24	III.	Tr. Egress, bisection	10 27 12		W. C.	
		last cont.	10 32 1		"	
	I.	Tr. Ingress, ext. cont.	11 44 49		"	
		bisection	11 48 41		"	
		int. cont.	11 51 40		"	
	I.	Tr. Ingress, bisection	11 48 40		W. J. C.	Very poor. Dancing.
25	I.	Ec. Reapp., first seen	11 23 33·5	−0 3·5	W. C.	
		½ light	11 25 32		"	
		full light	11 27 44		"	
25	I.	Ec. Reapp., first seen	11 23 49·0	+0 12	W. J. C.	
June 17	I.	Ec. Reapp., first seen	11 34 47	−0 14	W. C.	
		½ light	11 36 8		"	
		full light	11 37 20		"	

The duplicate observations on May 7, 1887, and on February 17, May 24 and 25, 1888, were made by Mr. Crofton with the Alvan Clark 5½-inch refractor.

Observers: S. J. P., W. J. C., and W. C. are MM. Perry, Crofton, and Carlisle.

Observations of Occultations of Stars by the Moon, taken at Stonyhurst. By the Rev. S. J. Perry, D.Sc., F.R.S.

1886.		Phen.	Star.	G.M.T. h m s	Limb.	Observer.	Remarks.
Nov.	7	Disapp.	5 Ceti	6 0 40·1	Dark	W. C.	
1887.							
Feb.	6	Disapp.	3 Cancri	9 28 27·76	Dark	W. J. C.	Good
Mar.	8	"	ρ Leonis	8 50 32·5	"	J. R.	Excellent.
"	29	"	θ^1 Tauri	9 12 1·2	"	W. C.	
"	29	"	θ^2 Tauri	9 19 8·8	"	"	
Apr.	2	"	B.A.C. 2731	8 56 4·3	"	"	
"	25	"	48 Tauri	8 55 3·7	"	W. J. C.	
"	25	"	"	8 55 4·1	"	W. C.	
Oct.	10	"	ζ^1 Cancri	15 40 52·2	Bright	W. J. C.	
"	10	"	"	15 40 52·2	"	W. C.	Poor: Limb tremulous.
"	10	Reapp.	"	16 22 44·5	Dark	"	Good.
"	10	"	ζ^2 Cancri	16 22 50·7	"	"	Fair.
Nov.	6	Disapp.	*g* Geminorum	10 30 18·4	Bright	"	
"	6	Reapp.	"	11 5 24·5	Dark	"	
"	20	Disapp.	B.A.C. 7209	5 35 16·7	"	"	
Dec.	27	"	75 Tauri	6 28 22·3	"	W. J. C.	
1888.							
Mar.	20	Disapp.	68 Orionis	10 15 47·1	"	W. C.	Pretty good.
"	20	"	"	10 15 47·9	"	W. J. C.	
"	20	Reapp.	"	11 20 48·9	Bright	W. C.	Fair.
May	20	Disapp.	*b* Virginis	12 55 30·5	Dark	"	Very good.
"	24	"	η Libræ	10 50 49·6	Bright	"	* very faint, difficult.
Sept.	14	"	50 Sagittarii	10 52 3·9	Dark	W. J. C.	Thin clouds passing.
Oct.	13	"	20 Capricorni	7 4 35·7		W. J. C.	
"	13	"	"	7 4 36·5		W. C.	

A dark screen was inserted in the eyepiece whenever the star was observed near the bright limb of the Moon. The observations of the Rev. W. J. Crofton were made with the 5½-inch refractor of Alvan Clark, and Mr. W. Carlisle always observed with the Simms 8-inch equatorial.

Note on the Occultation of χ^1 *Orionis*, 1888, *October* 24. By Rev. A. Freeman, M.A.

This was very well seen here. Star disappeared at $9^h\ 2^m\ 8^s{\cdot}02$ in a hollow of the Moon's bright limb, and reappeared almost instantly from behind the dark limb at $9^h\ 55^m\ 26^s{\cdot}56$. Both times G.M.T. The chronometer had been

compared by means of a deck-watch with the noon signal at the R.A.S. rooms. Approximate position of the Observatory, 51° 20′ 3″·1 N. and 2^m 59^s·67 E. Aperture of O.G. $3\frac{1}{2}$ in.

Murston Rectory, Sittingbourne:
1888, *October* 25.

Results of Micrometer Comparisons of Jupiter and β′ Scorpii in May 1888. By John Tebbutt.

This communication contains the results of filar-micrometer comparisons with the 8-inch equatorial of *Jupiter* and the well-known clock-star *β′ Scorpii* about the time of their conjunction in May last. In determining the difference of right ascension both limbs were observed at each transit over the single meridian thread of the micrometer. The correction for phase is insensible. In the determination of differences of declination the comparisons on each evening were equally divided between the north and south limbs. The differentials are corrected for refraction, and the resulting places of the planet for parallax. The steadiness and definition of the images were throughout satisfactory. In the last column will be found a comparison of the several stars with the theoretical places of the *Nautical Almanac*, from p. 352 of which work the place of the comparison star has been taken.

Results of Micrometer Comparisons of Jupiter and β′ Scorpii.

1888.	Windsor Mean Time.	Planet's Centre—Star. Δα	Δδ	Comps.	Planet's Geocentric Apparent α	δ	Obs.−N.A. α	δ
	h m s	m s	′ ″		h m s	° ′ ″	s	″
May 14	9 47 41	+3 28·99	−11 10·6	10	16 2 26·04	−19 41 4·1	+0·11	+0·9
„ 15	9 25 57	+2 58·23	− 9 47·3	20	16 1 55·29	−19 39 40·9	+0·17	+1·4
„ 16	9 15 9	+2 26·98	− 8 24·0	20	16 1 24·05	−19 38 17·7	+0·11	+0·8
„ 17	9 35 36	+1 54·89	− 6 57·6	20	16 0 51·98	−19 36 51·2	+0·03	+1·1
„ 18	10 0 53	+1 22·64	− 5 31·0	20	16 0 19·76	−19 35 24·6	+0·02	+1·0
„ 19	9 30 23	+0 51·59	− 4 6·8	20	15 59 48·71	−19 34 0·5	+0·02	+1·2
„ 20	10 41 49	+0 18·18	− 2 36·3	20	15 59 15·35	−19 32 29·9	+0·02	+1·5
„ 21	10 22 35	−0 13·25	− 1 11·6	20	15 58 43·92	−19 31 5·2	−0·02	+1·2
„ 22	9 25 19	−0 43·86	+ 0 11·2	20	15 58 13·30	−19 29 42·5	−0·09	+1·0
„ 23	9 32 29	−1 15·86	+ 1 38·1	20	15 57 41·31	−19 28 15·6	−0·11	+1·0
„ 24	9 46 35	−1 48·01	+ 3 5·7	20	15 57 9·18	−19 26 48·0	−0·14	+1·2
„ 25	10 14 3	−2 20·39	+ 4 34·2	20	15 56 36·82	−19 25 19·5	−0·15	+1·6

Errata in my former Communications in the "Monthly Notices."

January 1888, p. 135, line 33 from top, *for* ingress *read* egress.

April 1888, p. 314, line 14 from top, *insert* equation *between* the *and* Lenehan-White.

May 1888, p. 340, line 4 from top, *for* evening *read* morning.

Windsor, N.S. Wales: 1888, *August* 20.

Ephemeris for Physical Observations of the Moon. By A. Marth.
1889, January 1 to April 1.

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Geocentric Libration. Amount.	Geocentric Libration. Direction.
1889. Jan.	1	262°·68	+0°·28	+2·06	−1°·80	2°·73	228°·7
	2	274·87	0·26	3·72	−0·05	3·77	269·2
	3	287·06	0·23	5·11	+1·68	5·38	288·2
	4	299·25	0·20	6·14	3·26	6·95	298·0
	5	311·43	0·18	6·76	4·60	8·17	304·3
	6	323·61	+0·15	+6·96	+5·64	8·95	309·2
	7	335·78	0·13	6·76	6·36	9·28	313·5
	8	347·94	0·10	6·21	6·75	9·16	317·6
	9	0·10	0·07	5·34	6·82	8·65	322·1
	10	12·25	0·04	4·27	6·58	7·84	327·2
	11	24·40	+0·01	3·02	6·06	6·62	333·6
	12	36·54	−0·02	1·69	5·29	5·55	342·3
	13	48·68	−0·05	+0·34	+4·29	4·30	355·4
	14	60·82	0·08	−0·97	3·10	3·25	17·4
	15	72·95	0·12	2·20	1·77	2·82	51·2
	16	85·08	0·15	3·29	+0·34	3·31	84·1
	17	97·21	0·18	4·22	−1·12	4·37	104·9
	18	109·34	0·21	4·95	2·56	5·56	117·2
	19	121·47	0·24	5·46	3·88	6·70	125·5
	20	133·60	−0·28	−5·74	−5·04	7·63	131·4
	21	145·74	0·31	5·78	5·95	8·29	136·0
	22	157·88	0·34	5·58	6·55	8·59	139·8
	23	170·03	0·37	5·12	6·81	8·52	143·2
	24	182·19	0·39	4·42	6·67	8·00	146·6
	25	194·35	0·42	3·50	6·14	7·07	150·4
	26	206·52	0·44	2·39	5·23	5·75	155·5
	27	218·70	−0·47	−1·13	−3·97	4·13	164·1
	28	230·78	0·49	+0·23	2·48	2·49	185·3
	29	243·07	0·52	1·61	−0·77	1·78	244·4
	30	255·26	0·54	2·91	+0·96	3·07	288·2
	31	267·46	0·56	4·06	2·59	4·82	302·6
Feb.	1	279·66	0·58	4·97	4·05	6·41	309·2
	2	291·85	0·61	5·58	5·23	7·63	313·2
	3	304·04	−0·63	+5·83	+6·09	8·42	316·4

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Amount.	Direction.
1889.		°	°	°	°	°	°
Feb.	4	316·22	−0·65	+5·71	+6·60	8·72	319·3
	5	328·40	0·68	5·23	6·77	8·55	322·5
	6	340·58	0·70	4·43	6·62	7·97	326·3
	7	352·75	0·73	3·38	6·18	7·04	331·4
	8	4·92	0·76	2.15	5·47	5·88	338·6
	9	17·08	0·78	+0·81	4·54	4·61	349·9
	10	29·23	−0·81	−0·55	+3·41	3·45	9·1
	11	41·38	0·84	1·85	2·13	2·82	40·9
	12	53·52	0·86	3·01	+0·74	3·10	76·2
	13	65·66	0·89	3·97	−0·71	4·03	100·1
	14	77·80	0·92	4·68	2·14	5·15	114·6
	15	89·94	0·94	5·11	3·50	6·19	124·5
	16	102·07	0·97	5·24	4·71	7·04	132·0
	17	114·21	−0·99	−5·09	−5·68	7·62	138·3
	18	126·35	1·02	4·69	6·36	7·89	143·7
	19	138·50	1·04	4·08	6·67	7·82	148·7
	20	150·65	1·06	3·32	6·61	7·39	153·4
	21	162·81	1·08	2·45	6·15	6·62	158·3
	22	174·97	1·10	1·53	5·31	5·53	164·0
	23	187·14	1·12	−0·57	4·16	4·20	172·1
	24	199·32	−1·13	+0·38	−2·74	2·77	188·0
	25	211·50	1·15	1·33	−1·16	1·76	228·8
	26	223·69	1·17	2·23	+0·48	2·28	282·2
	27	235·89	1·18	3·07	2·09	3·71	304·3
	28	248·09	1·19	3·80	3·56	5·20	313·1
Mar.	1	260 29	1·21	4·37	4·79	6·48	317·7
	2	272·50	1·22	4·73	5·73	7·43	320·6
	3	284·71	−1·24	+4·82	+6·35	7·96	322·9
	4	296·91	1·25	4·62	6·62	8·06	325·2
	5	309·11	1·27	3·91	6·55	7·63	329·3
	6	321·31	1·28	3·31	6·18	7·01	331·9
	7	333·50	1·30	2·26	5·53	5·98	337·9
	8	345·69	1·32	+1·02	4·66	4·77	347·7
	9	357·87	1·33	−0·33	3·58	3·60	5·2
	10	10·05	−1·35	−1·70	+2·36	2·91	35·8
	11	22·22	1·36	3·01	+1·02	3·18	71·2
	12	34·38	1·38	4·15	−0·37	4·16	95·1
	13	46·54	1·39	5·04	1·78	5·34	109·5

Greenwich Noon.	Selenographica Colong. of the Sun.	Lat of the Sun.	Geocentric Libration. Long. of the Earth.	Lat. of the Earth.	Amount.	Direction.
1889.	°	°	°	°	°	°
Mar. 14	58·70	−1·41	−5·61	−3·13	6·42	119·2
15	70·86	1·42	5·81	4·36	7·26	127·0
16	83·01	1·44	5·63	5·38	7·78	133·8
17	95·16	−1·45	−5·08	−6·12	7·95	140·5
18	107·31	1·46	4·22	6·52	7·76	147·2
19	119·46	1·47	3·14	6·52	7·23	154·4
20	131·62	1·48	1·93	6·11	6·41	162·5
21	143·78	1·48	−0·71	5·32	5·36	172·4
22	155·95	1·49	+0·46	4·19	4·21	186·3
23	168·12	1·49	1·47	2·81	3·17	207·7
24	180·30	−1·50	+2·36	−1·27	2·68	241·8
25	192·49	1·50	3·10	+0·33	3·12	276·1
26	204·69	1·50	3·69	1·90	4·15	297·2
27	216·90	1·51	4·15	3·33	5·32	308·8
28	229·11	1·51	4·46	4·56	6·38	315·7
29	241·32	1·51	4·63	5·53	7·21	320·2
30	253·54	1·51	4·62	6·18	7·71	323·3
31	265·76	−1·51	+4·42	+6·50	7·85	326·0
April 1	277·98	1·52	3·98	6·49	7·61	328·6

The ephemeris is a continuation of that on p. 291 of the last volume.

Ephemerides of the Satellites of Saturn, 1888–89. By A. Marth. (Concluded.)

Approximate Differences of Right Ascension and Declination between the three Outer Satellites and the Centre of Saturn.

Greenwich Noon.	Titan. $\alpha_6 - A$	Titan. $\delta_6 - D$	Hyperion. $\alpha_7 - A$	Hyperion. $\delta_7 - D$	Iapetus. $\alpha_8 - A$	Iapetus. $\delta_8 - D$
1889.	s	″	s	″	s	″
Jan. 1	− 0·61	+46·7	+13·53	+43·2	+36·51	− 8·6
2	− 6·01	+34·2	+10·17	+53·7	37·95	7·2
3	−10·48	+16·2	+ 5·52	+57·4	+39·17	− 5·7
4	−13·35	− 4·4	+ 0·16	+54·1	40·16	4·1
5	−14·25	−24·5	− 5·24	+44·4	+40·91	− 2·5
6	−13·08	−41·2	−10·10	+30·0	41·41	− 0·8

Greenwich Noon. 1889.		Titan. α_6-A	Titan. δ_6-D	Hyperion. α_7-A	Hyperion. δ_7-D	Iapetus. α_8-A	Iapetus. δ_8-D
		s	″	s	″	s	″
Jan.	7	−10·04	−52·1	−14·00	+12·5	+41·65	+ 1·0
	8	− 5·57	−55·6	−16·71	− 6·2	41·64	2·8
	9	− 0·30	−51·3	−18·10	−24·5	+41·37	+ 4·6
	10	+ 5·02	−39·5	−18·19	−41·2	40·84	6·4
	11	+ 9·61	−21·7	−17·05	−55·2	+40·06	+ 8·2
	12	+12·71	− 0·6	−14·81	−65·7	39·02	10·0
	13	+13·79	+20·8	−11·63	−72·2	+37·73	+11·8
	14	+12·60	+38·9	− 7·71	−74·2	36·19	13·5
	15	+ 9·30	+50·5	− 3·31	−71·5	+34·42	+15·2
	16	+ 4·44	+53·8	+ 1·34	−64·0	32·42	16·8
	17	− 1·18	+48·1	+ 5·91	−52·0	+30·20	+18·3
	18	− 6·62	+34·5	+ 9·99	−36·0	27·78	19·7
	19	−11·03	+15·3	+13·24	−16·8	+25·17	+21·0
	20	−13·75	− 6·3	+15·26	+ 3·9	22·39	22·2
	21	−14·43	−27·1	+15·69	+24·4	+19·45	+23·2
	22	−13·03	−44·1	+14·32	+42·1	16·38	24·0
	23	− 9·76	−54·8	+11·20	+54·7	+13·19	+24·7
	24	− 5·10	−58·0	+ 6·66	+60·5	9·91	25·2
	25	+ 0·29	−52·8	+ 1·27	+58·8	+ 6·55	+25·5
	26	+ 5·64	−40·0	− 4·28	+50·0	+ 3·15	25·6
	27	+10·15	−21·0	− 9·36	+35·7	− 0·28	+25·4
	28	+13·08	+ 1·2	−13·56	+17·8	3·72	25·1
	29	+13·93	+23·3	−16·55	− 1·8	− 7·13	+24·6
	30	+12·48	+41·7	−18·21	−21·4	10·49	23·8
	31	+ 8·94	+53·2	−18·53	−39·5	−13·78	+22·8
Feb.	1	+ 3·89	+55·8	−17·57	−55·0	16·97	21·6
	2	− 1·81	+49·1	−15·47	−67·0	−20·05	+20·3
	3	− 7·22	+34·4	−12·40	−74·8	22·98	18·7
	4	−11·50	+14·2	− 8·54	−78·1	−25·75	+16·9
	5	−14·02	− 8·3	− 4·16	−76·3	28·34	15·0
	6	−14·46	−29·7	+ 0·53	−69·6	−30·74	+12·9
	7	−12·81	−46·8	+ 5·16	−58·0	32·91	10·6
	8	− 9·33	−57·4	+ 9·40	−42·0	−34·85	+ 8·2
	9	− 4·53	−59·9	+12·83	−22·5	36·55	5·7
	10	+ 0·92	−53·8	+15·16	− 1·0	−37·99	+ 3·1
	11	+ 6·23	−39·9	+15·86	+20·7	39·16	+ 0·4
	12	+10·60	−19·9	+14·82	+40·1	−40·05	− 2·3

Greenwich Noon. 1889.		Titan. $\alpha_6 - A$	Titan. $\delta_6 - D$	Hyperion. $\alpha_7 - A$	Hyperion. $\delta_7 - D$	Iapetus. $\alpha_8 - A$	Iapetus. $\delta_8 - D$
		s	"	s	"	s	"
Feb.	13	+ 13·32	+ 3·1	+ 11·98	+ 54·7	− 40·67	− 5·1
	14	+ 13·90	+ 25·8	+ 7·63	+ 62·5	− 41·01	− 7·9
	15	+ 12·20	+ 44·2	+ 2·33	+ 62·4	41·06	10·6
	16	+ 8·45	+ 55·3	− 3·27	+ 54·8	− 40·83	− 13·4
	17	+ 3·29	+ 57·1	− 8·50	+ 41·1	40·33	16·1
	18	− 2·42	+ 49·6	− 12·88	+ 23·1	− 39·55	− 18·7
	19	− 7·74	+ 33·8	− 16·09	+ 2·9	38·50	21·2
	20	− 11·84	+ 12·7	− 17·97	− 17·6	− 37·20	− 23·6
	21	− 14·13	− 10·4	− 18·51	− 36·8	35·66	25·8
	22	− 14·32	− 32·1	− 17·76	− 53·5	− 33·88	− 27·9
	23	− 12·45	− 49·1	− 15·84	− 66·8	31·88	29·9
	24	− 8·81	− 59·3	− 12·92	− 75·9	− 29·68	− 31·6
	25	− 3·92	− 61·0	− 9·20	− 80·2	27·29	33·1
	26	+ 1·52	− 54·0	− 4·90	− 79·6	− 24·73	− 34·5
	27	+ 6·72	− 39·2	− 0·29	− 73·7	22·01	35·6
	28	+ 10·91	− 18·5	+ 4·33	− 62·8	− 19·16	− 36·5
Mar.	1	+ 13·39	+ 5·1	+ 8·62	− 47·3	16·19	37·1
	2	+ 13·73	+ 27·9	+ 12·20	− 28·0	− 13·13	− 37·5
	3	+ 11·81	+ 46·1	+ 14·69	− 6·2	9·99	37·6
	4	+ 7·90	+ 56·6	+ 15·71	+ 16·2	− 6·80	− 37·5
	5	+ 2·68	+ 57·7	+ 15·00	+ 36·8	3·57	37·1
	6	− 2·97	+ 49·1	+ 12·52	+ 53·0	− 0·32	− 36·5
	7	− 8·14	+ 32·6	+ 8·48	+ 62·6	+ 2·92	35·6
	8	− 12·02	+ 10·9	+ 3·37	+ 64·3	+ 6·13	− 34·5
	9	− 14·06	− 12·4	− 2·14	+ 58·1	9·30	33·2
	10	− 14·03	− 34·0	− 7·41	+ 45·4	+ 12·41	− 31·6
	11	− 11·97	− 50·7	− 11·90	+ 27·9	15·43	29·8
	12	− 8·24	− 60·2	− 15·29	+ 7·8	+ 18·36	− 27·8
	13	− 3·33	− 61·2	− 17·39	− 13·0	21·17	25·6
	14	+ 2·03	− 53·4	− 18·16	− 32·8	+ 23·85	− 23·2
	15	+ 7·08	− 37·9	− 17·66	− 50·3	26·38	20·6
	16	+ 11·06	− 16·8	− 15·98	− 64·5	+ 28·74	− 17·9
	17	+ 13·30	+ 7·0	− 13·29	− 74·6	30·93	15·1
	18	+ 13·41	+ 29·6	− 9·79	− 80·1	+ 32·93	− 12·2
	19	+ 11·32	+ 47·2	− 5·67	− 80·5	34·73	9·2
	20	+ 7·34	+ 57·0	− 1·21	− 75·8	+ 36·32	− 6·1
	21	+ 2·14	+ 57·3	+ 3·32	− 66·0	37·69	− 3·0
	22	− 3·40	+ 48·0	+ 7·59	− 51·4	+ 38·82	+ 0·2

Greenwich Noon. 1889.	Titan. α_6-A	Titan. δ_6-D	Hyperion. α_7-A	Hyperion. δ_7-D	Iapetus. α_8-A	Iapetus. δ_8-D
	s	″	s	″	s	″
Mar. 23	− 8·38	+31·0	+11·25	−32·9	+38·72	+ 3·4
24	−12·03	+ 9·2	+13·92	−11·6	+40·39	+ 6·6
25	−13·86	−14·0	+15·24	+10·8	40·81	9·7
26	−13·64	−35·2	+14·93	+31·9	+40·99	+12·8
27	−11·47	−51·3	+12·88	+49·3	40·92	15·8
28	− 7·69	−60·1	+ 9·24	+60·5	+40·60	+18·8
29	− 2·83	−60·4	+ 4·46	+64·2	40·03	21·6
30	+ 2·42	−52·1	− 0·87	+59·8	+39·22	+24·2
31	+ 7·29	−36·2	− 6·08	+48·6	38·17	26·7
April 1	+11·06	−15·0	−10·65	+32·3	+36·89	+29·1
2	+13·09	+ 8·5	−14·19	+12·9	35·39	31·2
3	+13·02	+30·5	−16·52	− 7·6	+33·67	+33·2
4	+10·82	+47·5	−17·56	−27·4	31·74	34·9
5	+ 6·82	+56·5	−17·34	−45·3	+29·62	+36·4
6	+ 1·70	+56·0	−15·98	−60·1	27·32	37·6
7	− 3·69	+46·3	−13·60	−71·0	+24·86	+38·6
8	− 8·47	+29·2	−10·38	−77·5	22·25	39·4
9	−11·91	+ 7·6	− 6·53	−79·1	+19·50	+39·9
10	−13·55	−15·2	− 2·31	−75·8	16·63	40·1
11	−13·20	−35·6	+ 2·10	−67·4	+13·67	+40·0
12	−10·97	−50·9	+ 6·32	−54·3	10·63	39·6
13	− 7·20	−59·0	+10·03	−37·2	+ 7·53	+39·0
14	− 2·43	−58·7	+12·88	−16·9	4·39	38·2
15	+ 2·67	−50·1	+14·51	+ 4·7	+ 1·24	+37·1
16	+ 7·36	−34·3	+14·63	+25·8	− 1·91	35·7
17	+10·92	−13·3	+13·08	+43·8	− 5·03	+34·1
18	+12·78	+ 9·5	+ 9·95	+56·4	8·11	32·2
19	+12·59	+30·8	+ 5·58	+61·9	−11·12	+30·2
20	+10·34	+46·9	+ 0·53	+59·7	14·04	27·9
21	+ 6·38	+55·1	− 4·56	+50·5	−16·86	+25·5
22	+ 1·37	+54·1	− 9·16	+35·9	19·55	22·9
23	− 3·85	+44·3	−12·85	+17·8	−22·10	+20·2
24	− 8·43	+27·3	−15·42	− 1·7	24·49	17·4
25	−11·70	+ 6·2	−16·77	−21·0	−26·70	+14·5
26	−13·19	−15·8	−16·90	−38·8	28·72	11·5
27	−12·76	−35·4	−15·89	−53·9	−30·54	+ 8·4
28	−10·52	−49·8	−13·88	−65·4	32·15	5·3
29	− 6·80	−57·2	−11·01	−72·8	−33·53	+ 2·2

Greenwich Noon 1889.		*Titan.* α_6-A	*Titan.* δ_6-D	*Hyperion.* α_7-A	*Hyperion.* δ_7-D	*Iapetus.* α_8-A	*Iapetus.* δ_8-D
		s	″	s	″	s	″
April	30	− 2·15	−56·5	− 7·44	−75·8	−34·68	− 0·9
May	1	+ 2·79	−47·8	− 3·47	−73·9	−35·60	− 3·9
	2	+ 7·31	−32·2	+ 0·72	−67·2	36·28	6·9
	3	+10·71	−11·9	+ 4·85	−55·9	−36·71	− 9·8
	4	+12·44	+10·2	+ 8·60	−40·6	36·90	12·6
	5	+12·18	+30·4	+11·63	−22·0	−36·85	−15·3
	6	+ 9·92	+45·7	+13·59	− 1·5	36·56	17·9
	7	+ 6·03	+53·2	+14·16	+19·0	−36·03	−20·3
	8	+ 1·16	+51·8	+13·17	+37·2	35·28	22·5
	9	− 3·89	+42·0	+10·59	+50·9	−34·31	−24·6
	10	− 8·31	+25·5	+ 6·71	+58·1	33·12	26·5
	11	−11·42	+ 5·1	+ 2·01	+58·1	−31·73	−28·2
	12	−12·82	−15·9	− 2·92	+51·1	30·15	29·7
	13	−12·35	−34·5	− 7·51	+38·7	−28·39	−31·0
	14	−10·14	−48·2	−11·35	+22·4	26·47	32·1
	15	− 6·51	−54·9	−14·17	+ 4·2	−24·39	−33·0
	16	− 1·98	−54·0	−15·85	−14·2	22·17	33·6
	17	+ 2·81	−45·3	−16·36	−31·5	−19·82	−34·1
	18	+ 7·17	−30·2			17·37	34·4
	19	+10·44	−10·6			−14·83	−34·4
	20	+12·08	+10·4			12·21	34·2
	21	+11·79	+29·7			− 9·52	−33·9
	22	+ 9·58	+44·0			6·79	33·4
	23	+ 5·78	+50·9			− 4·03	−32·6
	24	+ 1·04	+49·3			− 1·27	31·7
	25	− 3·85	+39·7			+ 1·49	−30·7
	26	− 8·12	+23·8			4·23	29·5
	27	−11·12	+ 4·3			+ 6·94	−28·2

Approximate Greenwich Mean Times of Conjunctions of the Satellites with the Centre of the Planet, or of their Passages in the direction of the Minor Axis of the Ring.

1889.		h			h			h
Jan.	1	10·9 En. n.	Jan.	3	9·5 Te. n.	Jan.	5	6·8 Te. n.
		12·2 Rh. s.			12·2 En. s.			13·5 En. n.
		12·2 Te. n.			12·2 Mi. s.			17·4 Di. n.
		14·9 Di. s.			18·3 Rh. n.			20·8 Mi. n.
		15·0 Mi. s.		4	8·2 Te. s.		6	0·5 Rh. s.
	2	10·9 Te. s.			8·5 Di. s.			5·5 Te. s.
		13·6 Mi. s.			10·8 Mi. s.			6·0 En. s.
		19·8 En. n.			21·1 En. s.			19·4 Mi. n.
		23·7 Di. n.			22·1 Mi. n.			22·4 En. n.

1889.	h	
Jan. 7	2·2	Di. s.
	4·1	Te. n.
	14·9	En. s.
	18·0	Mi. n.
8	2·8	Te. s.
	6·7	Rh. n.
	7·3	En. n.
	11·0	Di. n.
	16·6	Mi. n.
	23·7	En. s.
9	1·4	Te. n.
	3·4	Tit. s. 50″
	15·2	Mi. n.
	16·2	En. s.
	17·8	Di. s.
10	0·0	Te. s.
	8·6	En. s.
	12·8	Rh. s.
	13·8	Mi. n.
	22·7	Te. n.
11	2·7	Di. n.
	12·4	Mi. n.
	17·5	En. s.
	21·3	Te. s.
12	9·9	En. n.
	11·1	Mi. n.
	11·5	Di. s.
	19·0	Rh. n.
	20·0	Te. n.
13	18·6	Te. s.
	18·8	En. n.
	20·3	Di. n.
	21·0	Mi. s.
14	11·2	En. s.
	17·3	Te. n.
	19·6	Mi. s.
15	1·2	Rh. s.
	5·1	Di. s.
	15·9	Te. s.
	18·2	Mi. s.
	20·1	En. s.
16	12·6	En. n.
	14·0	Di. n.
	14·6	Te. n.
	16·8	Mi. s.
	20·8	Tit. n. 50″
17	7·3	Rh. n.
	13·2	Te. s.
	22·8	Di. s.
18	11·9	Te. n.
19	7·6	Di. n.
	10·5	Te. s.
	13·5	Rh. s.
	22·7	En. s.
20	9·1	Te. n.
	15·2	En. n.
	16·4	Di. s.
	22·6	Mi. n.
21	7·6	En. s.
	7·8	Te. s.
	19·7	Rh. n.
	21·2	Mi. n.
Jan. 22	3·3	Di. n.
	6·4	Te. n.
	16·5	En. s.
	19·8	Mi. n.
23	5·1	Te. s.
	8·9	En. n.
	12·1	Di. s.
	18·4	Mi. n.
24	1·8	Rh. s.
	3·7	Te. n.
	17·0	Mi. n.
	17·8	En. n.
	20·9	Di. n.
25	0·7	Tit. s. 53″
	2·4	Te. s.
	10·2	En. s.
	15·6	Mi. n.
	20·4	Rh. ☌ Iap.
26	1·0	Te. n.
	5·7	Di. s.
	8·0	Rh. n.
	12·3	Iap. fn. 23″
	14·3	Mi. n.
	19·2	En. s.
	23·5	Iap. n. 26″
	23·7	Te. s.
27	10·8	Iap. pn. 28″
	11·6	En. n.
	12·9	Mi. n.
	14·6	Di. n.
	22·3	Te. n.
28	11·5	Mi. n.
	14·1	Rh. s.
	20·4	En. n.
	20·9	Te. s.
	22·8	Mi. s.
	23·4	Di. s.
29	10·1	Mi. n.
	12·9	En. s.
	19·6	Te. n.
	21·4	Mi. s.
30	8·2	Di. n.
	18·2	Te. s.
	20·0	Mi. s.
	20·3	Rh. n.
	21·7	En. s.
31	14·2	En. n.
	16·9	Te. n.
	17·0	Di. s.
	18·6	Mi. s.
Feb. 1	6·6	En. s.
	15·5	Te. s.
	17·2	Mi. s.
	18·3	Tit. n. 51″
	23·1	En. n.
2	1·9	Di. n.
	2·5	Rh. s.
	14·2	Te. n.
	15·5	En. s.
	15·9	Mi. s
Feb. 3	7·9	En. n.
	10·7	Di. s.
	12·8	Te. s.
	14·5	Mi. s.
4	8·6	Rh. n.
	11·5	Te. n.
	13·1	Mi. s.
	16·8	En. n.
	19·5	Di. n.
5	9·2	En. s.
	10·1	Te. s.
	11·7	Mi. s.
6	4·3	Di. s.
	8·7	Te. n.
	10·3	Mi. s.
	14·8	Rh. s.
	18·1	En. s.
7	7·4	Te. s.
	8·9	Mi. s.
	10·6	En. n.
	13·2	Di. n.
	20·2	Mi. n.
8	6·0	Te. n.
	18·8	Mi. n.
	19·4	En. n.
	20·9	Rh. n.
	22·0	Di. s.
9	4·7	Te. s.
	11·9	En. s.
	17·5	Mi. n.
	22·0	Tit. s. 55″
10	3·3	Te. n.
	6·8	Di. n.
	16·1	Mi. n.
	20·7	En. s.
11	2·0	Te. s.
	3·1	Rh. s.
	13·2	En. n.
	14·7	Mi. n.
	15·6	Di. s.
12	0·6	Te. n.
	13·3	Mi. n.
	22·1	En. n.
	23·3	Te. s.
13	0·5	Di. n.
	9·3	Rh. n.
	21·9	Te. n.
14	9·3	Di. s.
	20·5	Te. s.
15	15·4	Rh. s.
	15·8	En. n.
	18·1	Di. n.
	19·2	Te. n.
16	8·3	En. s.
	17·8	Te. s.

1889.	h	
	19·1	Mi. s.
Feb. 17	2·9	Di. s.
	15·8	Tit. n. 53″
	16·5	Te. n.
	17·1	En. s.
	17·7	Mi. s.
	21·6	Rh. n.
18	9·6	En. n.
	11·8	Di. n.
	15·1	Te. s.
	16·3	Mi. s.
19	13·8	Te. n.
	14·9	Mi. s.
	18·4	En. n.
	20·6	Di. s.
20	3·7	Rh. s.
	10·9	En. s.
	12·4	Te. s.
	13·5	Mi. s.
21	5·4	Di. n.
	11·1	Te. n.
	12·1	Mi. s.
	19·8	En. s.
22	9·7	Te. s.
	9·9	Rh. n.
	10·8	Mi. s.
	12·2	En. n.
	14·2	Di. s.
23	8·4	Te. n.
	9·4	Mi. s.
	20·7	Mi. n.
	21·1	En. n.
	23·1	Di. n.
24	7·0	Te. s.
	13·5	En. s.
	16·1	Rh. s.
	19·3	Mi. n.
25	5·6	Te. n.
	6·0	En. n.
	7·9	Di. s.
	17·9	Mi. n.
	19·5	Tit. s. 56″
26	4·3	Te. s.
	14·8	En. n.
	16·5	Mi. n.
	16·7	Di. n.
	22·2	Rh. n.
27	2·9	Te. n.
	7·3	En. s.
	15·1	Mi. n.
28	1·5	Di. s.
	1·6	Te. s.
	13·8	Mi. n.
	16·2	En. s.
Mar. 1	0·2	Te. n.
	4·4	Rh. s.
	8·6	En. n.
	10·4	Di. n.

	h	
	12·4	Mi. n.
	22·9	Te. s.
Mar. 2	11·0	Mi. n.
	17·5	En. n.
	19·2	Di. s.
	21·5	Te. n.
3	9·6	Mi. n.
	9·9	En. s.
	10·6	Rh. n.
	20·2	Te. s.
4	4·0	Di. n.
	8·2	Mi. n.
	18·8	En. s.
	18·8	Te. n.
5	11·2	En. n.
	12·9	Di. s.
	13·4	Tit. n. 54″
	16·7	Rh. s.
	17·0	Iap. ps. 34″
	17·5	Te. s.
	18·1	Mi. s.
6	4·8	Iap. s. 37″
	16·1	Te. n.
	16·5	Iap. fs. 39″
	16·8	Mi. s.
	20·1	En. n.
	21·7	Di. n.
7	12·5	En. s.
	14·8	Te. s.
	15·4	Mi. s.
	22·9	Rh. n.
8	6·5	Di. s.
	13·4	Te. n.
	14·0	Mi. s.
	21·4	En. s.
9	12·1	Te. s.
	12·6	Mi. s.
	13·9	En. n.
	15·3	Di. n.
10	5·1	Rh. s.
	6·3	En. s.
	* 9^m near.†	
	10·7	Te. n.
	11·2	Mi. s.
11	0·2	Di. s.
	9·4	Te. s.
	9·8	Mi. s.
	15·2	En. s.
12	7·6	En. n.
	8·0	Te. n.
	8·4	Mi. s.
	9·0	Di. n.
	11·3	Rh. n.
13	6·7	Te. s.
	16·5	En. n.
	17·1	Tit. s. 57″
	17·8	Di. s.
14	5·3	Te. n.

	h	
	8·9	En. s.
	17·4	Rh. s.
Mar. 15	2·7	Di. n.
	4·0	Te. s.
16	2·6	Te. n.
	10·3	En. n.
	11·5	Di. s.
	23·6	Rh. n.
17	1·3	Te. s.
	12·8	Mi. n.
	19·2	En. n.
	20·3	Di. n.
	23·9	Te. n.
18	11·5	Mi. n.
	11·6	En. s.
	22·6	Te. s.
19	5·2	Di. s.
	5·8	Rh. s.
	10·1	Mi. n.
	20·5	En. s.
	21·2	Te. n.
20	8·7	Mi. n.
	12·9	En. n.
	14·0	Di. n.
	19·9	Te. s.
21	5·4	En. s.
	7·3	Mi. n.
	11·3	Tit. n. 54″
	12·0	Rh. n.
	18·5	Te. n.
	18·6	Mi. s.
	21·8	En. n.
	22·8	Di. s.
22	14·2	En. s.
	17·2	Te. s.
	17·2	Mi. s.
23	6·7	En. n.
	7·7	Di. n.
	15·8	Te. n.
	15·9	Mi. s.
	18·2	Rh. s.
24	14·5	Te. s.
	14·5	Mi. s.
	15·0	En. n.
	16·5	Di. s.
25	8·0	En. s.
	13·1	Mi. s.
	13·1	Te. n.
26	0·4	Rh. n.
	1·4	Di. n.
	11·7	Mi. s.
	11·8	Te. s.
	16·9	En. s.
27	9·3	En. n.
	10·2	Di. s.
	10·3	Mi. s.
	10·4	Te. n.
28	6·6	Rh. s.

† The star is D.M. + 17°·2043; *v.* note, May 18.

1889.	h	
	8·9	Mi. s.
	9·1	Te. s.
	18·2	En. n.
	19·0	Di. n.
Mar. 29	7·6	Mi. s.
	7·7	Te. n.
	10·7	En. s.
	15·2	Tit. s. 56″
30	3·9	Di. s.
	6·4	Te. s.
	12·8	Rh. n.
	17·5	Mi. n.
31	5·0	Te. n.
	12·0	En. n.
	12·7	Di. n.
	16·1	Mi. n.
Apr. 1	3·7	Te. s.
	14·7	Mi. n.
	19·0	Rh. s.
	21·6	Di. s.
2	2·3	Te. n.
	13·3	En. s.
	13·3	Mi. n.
3	1·0	Te. s.
	5·8	En. n.
	6·4	Di. n.
	12·0	Mi. n.
	23·6	Te. n.
4	1·2	Rh. n.
	10·6	Mi. n.
	14·6	En. n.
	15·2	Di. s.
	22·3	Te. s.
5	7·1	En. s.
	9·2	Mi. n.
	20·9	Te. n.
6	0·1	Di. n.
	7·4	Rh. s.
	7·8	Mi. n.
	9·6	Tit. n. 53″
	16·0	En. s.
	19·6	Te. s.
7	6·4	Mi. n.
	8·4	En. n.
	8·9	Di. s.
	18·2	Te. n.
8	13·6	Rh. n.
	16·4	Mi. s.
	16·9	Te. s.
	17·3	En. n.
	17·8	Di. n.
9	9·7	En. s.
	15·0	Mi. s.
	15·6	Te. n.
10	2·6	Di. s.
	14·2	Te. s.
	19·8	Rh. s.
11	11·1	En. n.
	11·4	Di. n.
	12·2	Mi. s.
	12·9	Te. n.
Apr. 12	10·8	Mi. s.
	11·5	Te. s.
	20·3	Di. s.
13	2·0	Rh. n.
	9·5	Mi. s.
	10·2	Te. n.
	12·4	En. s.
14	5·1	Di. n.
	8·1	Mi. s.
	8·8	Te. s.
	13·7	Tit. s. 55″
15	0·5	Iap. fn. 35″
	7·5	Te. n.
	8·2	Rh. s.
	11·9	Iap. n. 37″
	13·7	En. n.
	14·0	Di. s.
	23·3	Iap. pn. 39′,
16	6·1	Te. s.
	6·2	En. s.
	16·6	Mi. n.
	22·8	Di. n.
17	4·8	Te. n.
	14·4	Rh. n.
	15·1	En. s.
	15·3	Mi. n.
18	3·5	Te. s.
	7·5	En. n.
	7·7	Di. s.
	13·9	Mi. n.
19	2·1	Te. n.
	12·5	Mi. n.
	16·4	En. n.
	16·5	Di. n.
	20·7	Rh. s.
20	0·8	Te. s.
	8·9	En. s.
	11·1	Mi. n.
	23·4	Te. n.
21	1·4	Di. s.
	9·7	Mi. n.
	22·1	Te. s.
22	2·9	Rh. n.
	8·3	Tit. n. 52″
	8·4	Mi. n.
	10·2	En. n.
	10·2	Di. n.
	20·7	Te. n.
23	19·1	Di. s.
	19·4	Te. s.
24	9·1	Rh. s.
	11·5	En. s.
	16·9	Mi. s.
	18·1	Te. n.
25	3·9	Di. n.
	15·5	Mi. s.
	16·7	Te. s.
Apr. 26	12·8	Di. s.
	12·9	En. n.
	14·2	Mi. s.
	15·3	Rh. n.
	15·4	Te. n.
27	12·8	Mi. s.
	14·0	Te. s.
	21·6	Di. n.
28	11·4	Mi. n.
	12·7	Te. n.
	14·2	En. s.
	21·6	Rh. s.
29	6·5	Di. s.
	6·6	En. n.
	10·0	Mi. s.
	11·4	Te. s.
30	10·0	Te. n.
	12·7	Tit. s. 53″
	15·3	Di. n.
	15·5	En. n.
May 1	3·8	Rh. n.
	8·0	En. s.
	8·7	Te. s.
2	0·2	Di. s.
	7·3	Te. n.
	16·9	En. s.
3	6·0	Te. s.
	9·0	Di. n.
	9·3	En. n.
	10·0	Rh. s.
4	4·6	Te. n.
	14·4	Mi. n.
	18·0	Di. s.
5	3·3	Te. s.
	10·7	En. s.
	13·1	Mi. n.
	16·3	Rh. n.
6	2·0	Te. n.
	2·7	Di. n.
	11·7	Mi. n.
7	0·6	Te. s.
	11·6	Di. s.
	12·0	En. n.
	22·5	Rh. s.
	23·3	Te. n.
8	7·5	Tit. n. 50″
	20·5	Di. n.
	21·9	Te. s.
9	13·3	En. s.
	20·6	Te. n.
10	4·8	Rh. n.
	5·3	Di. s.
	19·3	Te. s.
11	14·2	Di. n.
	17·9	Te. n.
12	11·0	Rh. s.
	16·6	Te. s.
	23·0	Di. s.
13	15·3	Te. n.

1889.	h		h		h
May 14	7·9 Di. n.		* 9ᵐ near.†		21·9 Di. s.
	13·9 Te. s.	May 19	5·8 Rh. n.	May 24	0·5 Te. s.
	17·2 Rh. n.		7·2 Te. n.		1·3 Iap. ps. 29″
15	12·6 Te. n.		19·3 Di. n.		7·0 Tit. n. 47″
	16·8 Di. s.	20	5·9 Te. s.		13·4 Iap. s. 31″
16	11·2 Te. s.	21	4·2 Di. s.		23·2 Te. n.
	12·1 Tit. s. 51″		4·6 Te. n.	25	1·5 Iap. fs. 33″
	23·5 Rh. s.		12·0 Rh. s.		6·8 Di. n.
17	1·6 Di. n.	22	3·2 Te. s.		21·9 Te. s.
	9·9 Te. n.		13·0 Di. n.	26	0·5 Rh. s.
18	8·6 Te. s.	23	1·9 Te. n.		
	10·5 Di. s.		18·3 Rh. n.		

† The star is D.M. + 17°·2043, and is also found in the Markree Cat. IV. p. 121, but does not seem to have been observed with meridian instruments anywhere. As the D.M. place gives an occultation by *Saturn* on May 18, it would be desirable that the accurate position of the star should be determined by timely observations in the meridian, so that the circumstances of the occultation or close conjunction may be computed in good time before its occurrence. The D.M. magnitude of the star in $9^{m}\cdot1$ and its place for 1889·0 α 9^h 9^m 12^s $\delta + 17°$ $35'\cdot6$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. DECEMBER 14, 1888. No. 2

E. J. STONE, M.A., F.R.S., Vice-President, in the Chair.

John Harvey Jones, Fairview Villa, Coburg Road, Montpelier, Bristol;
William Henry Maw, 18 Addison Road, Kensington, W.; and
Albert Taylor, Hurstside, West Molesey, Surrey;

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

Wm. Henry Fisher Alexander, B.A., 26 Bousfield Road, St. Catherine's Park, S.E. (proposed by J. A. Barringer);
John Cockburn, New Club, Edinburgh (proposed by H. H. Turner);
Thomas Keig, Prospect Hill, Douglas, Isle of Man (proposed by Isaac Roberts);
Arthur Courtauld Willoughby Lowe, B.A., Gosfield Hall, Halstead, Essex, and 76 Lancaster Gate, Hyde Park, W. (proposed by E. J. Lowe);
Arthur B. P. Mee, Llanelly, Carmarthenshire (proposed by George Calver);
Captain A. T. Miller, R.N., H.M.S. *Conway*, Birkenhead (proposed by Charles Barton);
Kenneth James Tarrant, Letchford House, Hatch End, Pinner (proposed by Arthur Cottam).

On the Retrogradation of the Plane of Saturn's Ring and of those of his Satellites whose Orbits coincide with that Plane. By Professor J. A. C. Oudemans.

Being occupied—in behalf of the second volume of the fourth edition of Kaiser's *Sterrenhemel*—with a discussion of the elements of the satellites and the ring of *Saturn*, I was struck by the following circumstance.

As is generally known, Bessel occupied himself at three different epochs with a research on the apparent diameter and the position of the ring of *Saturn*, 1° in 1812, *Königsberger Archiv für Naturwissenschaften und Mathematik*, 1812, 11 Band, p. 113; 2° in 1818, *Berl. Jahrbuch*, 1829, p. 175; and 3° in 1830–35, *Astronomische Nachrichten*, vol. xii. p. 153. These three papers* have been reproduced by Engelmann in his edition of Bessel's *Abhandlungen*, vol. i. pp. 110, 319 and 150 respectively.

In his first paper Bessel determined the inclination of the ring, using his measures both of the major and of the minor axis, made at a time when it was widely open, in Schröter's observatory at Lilienthal, by the method of projections. The longitude of the node was found by discussing the observations of disappearance and reappearance of *Saturn's* ring, made by several astronomers from 1714 to 1803.

If there were no retrogradation of the ring, the yearly increase of the node's longitude should necessarily have been put $=50''\cdot2$, but Bessel found this increase to be only $40''\cdot57$, admitting thus a retrogradation of about $9''\cdot6$; he did not distinctly pronounce himself on what manner this retrogradation is found, but from the connection between the different parts of the paper I think we must conclude that, as in his third paper, it was introduced as an unknown quantity into the equations formed by the disappearances and reappearances of the ring.

In his second paper Bessel gives the measures of the inclination of the ring, made in 1818 with very moderate means; in fact, the instrument employed was an equatorial of Dollond, provided with a telescope of 16 inches (focal distance); in the field of the strongest eyepiece there was stretched a single wire, and by moving the instrumental arc of this instrument till this wire was parallel to the major axis of the ring, and by reading the latitude-arc and the noniuses, the inclination of the ring to the vertical was found. It is not surprising that these observa-

* Professor E. S. Holden, comparing his and Professor Asaph Hall's determinations of the inclination of *Saturn's* ring, made at Washington during the years 1877, 1878, and 1879, with Bessel's (*Monthly Notices*, April 1882), overlooks the last and most renowned determination, and cites only that of 1818. This explains the large probable error of a single observation of Bessel's, viz. $24'\cdot1$, whereas Hall's is found to be $8'\cdot6$, and Holden's $10'\cdot3$.

tions (the only one cited by Professor Holden) possess the relatively high probable error of $\pm$ 24′·1.

Bessel became possessed of a heliometer in March 1829, and in his third paper he follows the same method as in his first; 131 measures, made with the heliometer, of the inclination of the major axis of the ring, taken at an epoch when it was very narrow, gave him 67 equations between δn, δi and m, where

δn is the correction of the adopted node, 167° 21′ 0″, for 1833;

δi, the correction of the adopted inclination, 28° 9′ 30″, for 1833; and

m, the annual variation of the node of the ring's plane on that of the planet's orbit;

and the observed disappearances and reappearances of the ring gave between the same unknown quantities 20 equations, out of which only 15 have regard to observations made on two successive days, viz. before and after the phenomenon, and these equations alone were taken into account.

The 67 equations of the first order, of weights varying from 1 to 4, have all small coefficients of δn and m, but a negative coefficient of δi not much differing from unity, so they have been combined according to their weight, and gave the following mean equation:

$$(131 \text{ observations}) \ldots 0 = 65''\cdot2 + 0\cdot0452\,\delta n - 0\cdot9647\,\delta i + 0\cdot25\,m.$$

The fifteen equations of the second order have all nearly the same positive or negative coefficient of δn, viz. from 0·4700 to 0·4710. The coefficients of δi have all their signs contrary to that of δn, and a value of from 0·0657 to 0·0894. Excepting the two last equations given by the observations of the disappearance on April 26 and the reappearance on June 13, 1833 (i.e. *after* the epoch 1833·0), the coefficient of m has the same sign as that of δn, but it diminishes from 53·28 (1714, October 15) to almost naught. (N.B. 0·47 is the sine of the inclination 28° 9′ 30″ and the coefficient of m is = the coefficient of δn multiplied by the number of years before the epoch.)

Believing (probably after the result of his former investigation) that the value of m was nearly = 10″, Bessel introduced the new unknown quantity $m' = m - 10$, but afterwards he returned to m, and accordingly we will employ this letter only. Treating the fifteen equations of the second order by the method of least squares, Bessel found:

$$0 = +151\cdot59 + 3\cdot3205\,\delta n - 0\cdot5486\,\delta i + 167\cdot949\,m$$

$$0 = -23577 + 167\cdot949\,\delta n - 27\cdot317\,\delta i + 12635\cdot3\,m$$

Combining these equations with the one given above,* Bessel found:

* This equation is repeated in Bessel's paper, in the *Astronomische Nachrichten*, in column 167, but with the wrong sign of the term containing δi ($+0\cdot9647\,\delta i$, instead of $-$), and this error is repeated in the reprint in Engelmann's edition of the *Memoirs of Bessel*.

$$\left.\begin{aligned}\delta i &= +\ 63'',1\\ \delta n &= -137'',9\\ m &= +\ \ 3'',848\end{aligned}\right\}*$$

and as

$$n = 167^\circ\ 21'\ \ 0'' + \delta n + (50''\cdot 125 - 0\cdot 95206\,m)\,(\mathrm{T} - 1833)$$
$$i = \ 28^\circ\ \ 9'\ 30'' + \delta i - (\ 0''\cdot 487 - 0\cdot 03553\,m)\,(\mathrm{T} - 1833)$$

he gives his result in the following shape:

$$n = 166^\circ\ 53'\ \ 8''\cdot 9 + 46''\cdot 462\,(\mathrm{T} - 1800)$$
$$i = \ 28^\circ\ 10'\ 44''\cdot 7 - \ 0''\cdot 350\,(\mathrm{T} - 1800)$$

in which they are generally adopted. The astronomical almanacs start from these formulæ to calculate annually the elements of *Saturn's* ring, &c. Even those astronomers who make researches upon the orbits of the satellites, so far as they assume these orbits to coincide with the plane of the ring, accept them as established facts.

It appears to me that the result, published by Bessel, is not so accurate and trustworthy as it seems to be. The coefficient $46''\cdot 462$ is given to a thousandth of a second, but I have a strong doubt whether even the units are to be depended upon.†

Bessel has not added any discussion of the probable errors of his results, though this was not very troublesome. The equations of the first order stand apart, they can only serve to determine δn; after having substituted into them the values of the unknown quantities, there remain sixty-seven errors. Squaring them and multiplying each square by the weight, the result is (m being the mean error):—

$$\begin{aligned}(67-1)\,\mathrm{m}^2 &= 22458\\ \mathrm{m}^2 &= \ \ 340\cdot 3\\ \mathrm{m} &= \pm\ \ 18'\cdot 45 \quad (0\cdot 6745\,\mathrm{m} = \pm\,12'\cdot 44).\end{aligned}$$

The equations of the second order that served to determine δn and m were only fifteen in number. Since the laws of the oscillations of the rings are unknown, we are obliged, if we wish to form a judgment on the uncertainty of the result, to consider the remaining differences as errors of observation. So we obtain for these equations:

$$\begin{aligned}(15\ \ 2)\,\mathrm{m}^2 &= \ 253\cdot 07\\ \mathrm{m}^2 &= \ \ \ 19\cdot 47\\ \mathrm{m} &= \pm\ 4'\cdot 41\end{aligned}$$

* This solution is not exact. The true values are given below.

† It seems to me to be an abuse of the method of least squares to publish a result with more than one figure than can be accounted for, and especially, as was here the case, if the mean or probable error is not added. *One* figure may be admitted, to indicate if the last figure but one be full or not full. Encke's famous value *in four decimals!* of the Sun's parallax, $8''\cdot 5776$, and still more his second improved one IN FIVE DECIMALS!! $8''\cdot 57116$, *whereas the first decimal was wrong*, ought to be a warning example to every astronomical calculator.

Adding now the mean and probable errors to the values of the unknowns as we found them, we have:

	Equation of the order.	Weight.	Value found.		Mean Error.	Probable Error.
δi	1st	1·31	$+ 62''\cdot1$	$= +1'\cdot0$	$\pm 1'\cdot6$	$\pm 1'\cdot1$
δn	2nd	1·08	$-138''\cdot1$	$= -2'\cdot3$	$\pm 4'\cdot2$	$\pm 2'\cdot9$
m	2nd	4139·6	$+ 3''\cdot836$		$\pm 4''\cdot1$	$\pm 2''\cdot8$

Thus we see that the value found by Bessel for m, i.e. the yearly retrogradation of *Saturn's* ring, with respect to his orbit, though larger than its probable error, is at all events smaller than its mean error.

Let us consider now the theoretical value of this retrogradation. Laplace has already, in his most splendid *Mécanique Céleste*, treated the subject, and though we are now able to substitute better values for the constants he employs, his results are still of force. In the Fifth Book he proves that those satellites whose orbits lie in the plane of the planet's equator (i.e. all except *Iapetus*) are kept in that plane by the rotating and elliptic planet, and as the ring may be considered as an aggregation of satellites it is in the same case. And he closes that book by the remark, that *Saturn's* equator, in its very slow motion, caused by the action of the Sun and *Iapetus*, carries with it the planes of the rings and of the satellites.

In § 37 of the Eighth Book he finds for the solar precession of Saturn

$$0\cdot878 \text{ centesimal seconds} = 0''\cdot2845,$$

and for that due to the action of *Iapetus*

$$6195 \text{ centesimal seconds} \times L = 2007''\cdot2\ L,$$

L being the mass of this satellite, that of *Saturn* being taken as unity. By the fact that there has not been found any inclination of *Titan's* orbit to the ring's plane, nor the existence of a fixed plane, making an angle with the ring's plane, and with which *Titan's* orbit makes a constant angle, whereas the line of the nodes has a retrograde motion, Laplace proves that the mass of *Iapetus* is very small—smaller, indeed, than $\frac{1}{200}$th of that of *Saturn*. We may go farther, thanks to the beautiful photometric investigations of Professor Pickering. Taking as an approximation, according to Table LII. on p. 269 of the Ninth Volume of the "Annals of the Harvard College Observatory," the equivalent *mean* diameter of *Iapetus* $= 0\cdot0069 \times$ that of *Saturn*, and the ellipticity of that planet $= \frac{1}{9\cdot2}$, we have:

$$\text{Volume of } Iapetus = \frac{9\cdot2}{8\cdot2} \cdot 0\cdot0069^3 \text{ volume of } Saturn$$

$$= 0\cdot000000368 37 \text{ volume of } Saturn$$

$$= \frac{1}{2713000} \text{ volume of } Saturn.$$

Knowing nothing about the density of this satellite, the safest way is to take it equal to that of the planet, then the satellite's mass is expressed by the same fraction, that of *Saturn* being taken as unity. And so we find for the precession of *Saturn's* equator due to *Iapetus* the approximate value of 0''·00074.

I have myself made the calculation of these precessions in the following way:—Supposing the densities of the ellipsoidic layers in the Earth and in *Saturn* to follow the same law, and putting

	For the Earth.	For *Saturn*.
The solar precession	ψ_e	ψ_s
The time of the rotation on the axis	d_e	d_s
The excentricity of the meridian	e_e	e_s
The inclination of the equator upon the plane of the orbit	i_e	i_s
The mean distance from the Sun	a_e	a_s
The angle of excentricity of the orbit	ϕ_e	ϕ_s.

we have:

$$\psi_e : \psi_s = \frac{d_e e_e^2 \cos i_e}{a_e^3 \cos^3 \phi_e} : \frac{d_s e_s^2 \cos i_s}{a_s^3 \cos^3 \phi_s}$$

Taking

$$\begin{array}{ll} d_e = 1436^m & d_s = 615^m \\ e_e^2 = \dfrac{1}{145} & e_s^2 = \dfrac{9{\cdot}2^2 - 8{\cdot}2^2}{9{\cdot}2^2} = \dfrac{17{\cdot}4}{84{\cdot}64} \\ i_e = 23^\circ\ 27'{\cdot}3 & i_s = 26^\circ\ 49'{\cdot}5 \\ a_e = 1 & a_s = 9{\cdot}53885 \\ \phi_e = 0^\circ\ 57'{\cdot}65 & \phi_s = 3^\circ\ 12'{\cdot}9 \\ \psi_e = 15''{\cdot}82^* & \end{array}$$

we find:

$$\psi_s = 0''{\cdot}2273.$$

To compare further the action of the Sun ψ_s to that of *Iapetus* ψ_j, we have:

$$\psi_s : \psi_j = \frac{\text{Mass of Sun} \times \cos i_s}{a_s^3 \cos^3 \phi_s} : \frac{\text{Mass of } \textit{Iapetus} \times \cos \mathrm{I}}{a_j^3 \cos^3 \phi_j}.$$

* There is an uncertainty of a little more than 0''·1 in this quantity. Adopting the lunisolar precession = 50''·35, and the Moon's mass = $\frac{1}{81{\cdot}5}$, I get 15''·93. Nyrén takes the lunisolar precession for 1850 = 50·3164, which value he deduced from the catalogues of Weisse and of Schjellerup (*Bestimmung der Nutation der Erdachse*, St. Petersburg, 1872, p. 54). From his nutation-constant I find the Moon's mass = $\frac{1}{80{\cdot}5}$ and the solar precession 15''·79; but if I take the lunisolar precession to be = 50''·35, more conform to Ludwig Struve's last determination, we get 15''·82 for the solar only, as we have adopted above.

I signifying the inclination of the orbit of *Iapetus* upon the equator of *Saturn* $= 13° 28'$:

a_j, the semi-axis major of *Iapetus's* orbit $= a_s \sin 515''\cdot5$

ϕ_j, the angle of excentricity of *Iapetus's* orbit $= 1° 35'\cdot6$.

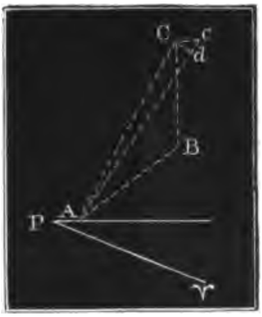
The result is:

$$\psi_j = 0''\cdot001665$$

But this regards a turning of the pole of *Saturn's* equator around the pole of *Iapetus's* orbit, whereas we must find the turning of the same pole around the pole of *Saturn's* orbit.

Let, in the accompanying diagram,

A be the pole of *Saturn's* orbit,
B that of *Iapetus's* orbit,
C that of *Saturn's* equator,
P that of the ecliptic,
♈ the vernal equinox.



We have for 1850:

$$\begin{aligned} ♈\,PA &= 22° 21' \\ PA &= 2\ \ 30 \\ ♈\,PB &= 52\ \ 28 \text{ and } APB = 30° 7' \\ PB &= 18\ \ 39 \\ ♈\,PC &= 77\ \ 36 \text{ and } APC = 55° 15' \\ PC &= 28\ \ 10 \end{aligned}$$

And herewith we find:

$$AB = 16° 32' \qquad AC = 26° 48'\cdot8$$

$$PAB = 145\ \ 40\cdot5 \qquad PAC = 120\ \ 42\cdot4$$

$$\therefore CAB = 24° 58'\cdot1$$

In the spherical triangle ABC, AB, AC and the angle BAC being known, we find:

$$BC = 13° 36' \qquad \text{Angle } C = 30° 43'$$

The turning around B takes place in the directions C*c*, perpendicular to BC, but we want to know the turning around A, so letting fall the perpendicular C*d* we have:

$$\mathrm{C}c = \psi_j \sin \mathrm{BC}$$
$$\mathrm{C}d = \mathrm{C}c \cos \mathrm{C}$$
$$\mathrm{CA}d = \frac{\mathrm{C}d}{\sin \mathrm{AC}} = \frac{\sin \mathrm{BC} \cos \mathrm{C}}{\sin \mathrm{AC}} \cdot \psi_j$$
$$= 0''\cdot000746$$

in full accordance with Laplace. Adding the solar precession 0''·2273, the *Iapeti-solar* precession becomes 0''·2280.

There remains now to consider the action of the ring, retrograding itself by the Sun's attraction, on the planet.

The ring may be considered as an aggregation of satellites. Taking the mean semi-diameter of the ring at *Saturn's* mean distance = 16''·75, we find, by comparison with the satellites, the time of rotation = 0·4647 days = t.

The same element of *Saturn* is 10759 days = T.

A fair approximation of the time of retrogradation of the nodes of such a satellite is (Möbius, *Mechanik des Himmels*, p. 223):

$$\frac{4}{3} \cdot \frac{T^2}{t} \text{ days} = 322200000 \text{ days}$$
$$= 909500 \text{ years.}$$

So that the yearly retrogradation of the ring's node, if the planet were not elliptical, should be

$$1''\cdot425.$$

If the ring were solidly attached to the planet it would draw it along, and the result would be a retrogradation between 0''·228 and 1''·425, easily to be determined, taking into account the proportion of the different moments of inertia.

Calculating only the moments of inertia with regard to the rotatory axis, we find

Mom. of inertia of planet = mass of planet $\times \frac{2}{5} a^2$

" " of the ring = mass of the ring $\times \frac{1}{2} (r^2 + r'^2)$.

Taking

$r' = 19''\cdot75$, the outer radius of the ring,

$r = 13''\cdot75$, the inner radius of the ring,

$a = 8''\cdot65$, the radius of *Saturn's* equator

(the final values, which we arrived at after careful discussion) we find, if the mass of the ring $= \frac{1}{\mu} \times$ the mass of *Saturn*:

$$\frac{\text{Moment of inertia of ring}}{\text{Moment of inertia of } Saturn} = \frac{9\,688}{\mu}.$$

The fraction $\frac{1}{\mu}$ is yet very uncertain. Bessel, disregarding the ellipticity of the planet, made it $\frac{1}{118}$, but was, of course, aware that this value was too great. Tisserand, to explain a very vague expression of Captain Jacob: "The apsides (of *Mimas*) seem to have made nearly a semi-revolution in the course of a year," and having found by theory that by the planet's ellipticity alone the line of *Mimas's* apsides has a yearly motion of 349°, supposes that motion to have been (between January 1857 and January 1858, the epochs of Jacob's observations) $1\frac{1}{2}$ revolution, and in that supposition

$$\text{" On trouverait } \frac{m}{M} = \frac{1}{620}; \text{"}$$

but, considering that the observations of Professor Asaph Hall at Washington, made with much more powerful means than Jacob's, do not reveal an ellipticity of the orbit of *Mimas*, I believe this value cannot be properly named a result, especially as Jacob himself acknowledges (*Memoirs Royal Astronomical Society*, vol. xxviii. p. 69) "The observations registered of *Enceladus* and *Mimas* are in general little better than *estimates* of the direction," and as an error in the position-angle is enlarged when reduced to an error in the satellite's kronocentric longitude, the observations of these satellites being taken only in the elongations.

The latest valuation of the ring's mass is that of Hermann Struve,* who, consulting the motions of the apsides, both the direct one of *Titan* and the retrograde one of *Hyperion*, and adopting the best available measures of *Saturn's* equatorial and polar diameters, treats the problem as leading to two equations with two unknowns, viz. the mass of *Titan* (which is found $\frac{1}{4678}$), and the mass of the ring, for which is found the *superior limit* of $\frac{1}{314}$.

Adopting this value, we find for the superior limit of the moments of inertia of the ring and the planet about $\frac{1}{32 \cdot 4}$, and so the common retrogradation of the ring and the planet could not rise higher than

$$0''\cdot 228 + \frac{1}{33 \cdot 4} \times 1''\cdot 197 = 0''\cdot 264.$$

Now the ring is not solidly attached to the planet, but as the spheroidic planet keeps the ring in the plane of the equator, the

* In his beautiful memoir: *Beobachtungen der Saturnstrabanten*, 1ᵉ Abtheilung, 'Beobactungen am 15-zölligen Refractor.' Supplément I. aux *Observations de Poulkova*, St. Pétersbourg, 1888.

effect is likely to be not much less, and so I believe that, taking a round number,

$$0''\cdot 25,$$

is a fair approximation to the precessional retrogradation of the ring and planet together.

I return to Bessel's solution. Bessel gave his results in a form as if the mean epoch of the observations were 1800, but, on the contrary, it was 1833·0 for his own determinations of the inclination, and 1780 for the determination of the node. The consequence is that if we do not adopt the retrogradation of the node found by him ($3''\cdot 848$) we shall find another longitude of it for 1800, but the same for 1780 and this one with the maximum of weight. Indeed, we find for 1780

Weight.	Mean error of δn.	Probable error.
3·295	$\pm 2'\cdot 4$	$\pm 1'\cdot 6$

The yearly increase of the longitude of the ring's node with the ecliptic becomes now:

$$50''\cdot 125 - 0\cdot 95206\, m = 49''\cdot 89$$

And so there follows from our considerations that the results of Bessel's investigation ought to be written in the following way:

	Probable Error.	Yearly Variation.
For 1780 : $n = 166^\circ\ 37'\cdot 7$	$\pm 1'\cdot 6$	$+49''\cdot 89 = +0'\cdot 8315$
For 1833 : $i = 28\ \ 10\cdot 7$	$\pm 1\cdot 1$	$-\ 0\cdot 48 = -0\cdot 0080$

or in other words:

$$n = 166^\circ\ 37'\cdot 7 + 0'\cdot 8315\,(T-1780),$$
$$i = 28^\circ\ 10'\cdot 7 - 0'\cdot 0080\,(T-1833).$$

The difference between my result and Bessel's is not so very small; it is $3''\cdot 6$ per annum. Bessel's mean year (not given by him) was 1780; consequently we have now the effect of 109 years, and $109 \times 3''\cdot 6 = 392'' = 6'\cdot 5$. But as *Saturn* is at a distance of nearly 10 unities, a change of direction of the node-line of $6'\cdot 5$ corresponds in the neighbourhood of the Sun to about 1° of the circumference of the Earth's orbit. Thus the difference in a disappearance or reappearance when the Earth passes the plane will be *one day at least*, but generally more; and when the *Sun* passes the plane, it is at least three days, owing to the so much slower motion of *Saturn*.

Since 1835 we have had three epochs of disappearances and reappearances of the ring, viz. 1848–49, 1861–62, and 1878, and the next to come is 1891. In the following table I have collected the times of disappearance and reappearance according to Bessel, and I have added the correction, necessary if our formula be adopted.

		Authority.	Epoch according to Bessel.		Correction.	Resulting epoch.		
				h	d h		h	
1848	Disappearance	B. J.	April 21	21·4	−0 14·8	April 21	6·6	♁
	Reappearance	„	Sept. 3	3·3	+1 23·0	Sept. 5	2·3	⊙
	Disappearance	„	„ 12	12·8	+0 22·2	„ 13	11·0	♁
1849	Reappearance	„	Jan. 19	8·3	−0 15·4	Jan. 18	16·9	♁
1861	Disappearance	„	Nov. 23	1·05	+1 7·6	Nov. 24	8·65	♁
1862	Reappearance	„	Jan. 31	19·5	−1 9·6	Jan. 30	9·9	♁
	Disappearance	„	May 18	2·8	+2 7·1	May 20	9·9	⊙
	Reappearance	„	Aug. 12	20·2	+0 16·4	Aug. 13	12·6	♁
1878	Disappearance	N. A.*	Feb. 6	11	+2 20	Feb. 9	7	⊙
	Reappearance	„	Mar. 1	4	−0 18·6	Mar. 0	9·4	♁
1891	Disappearance	„	Sept. 22	18·9	+0 21·0	Sept. 23	15·9	♁
	Reappearance	„	Oct. 30	10·9	+3 6·0	Nov. 2	16·9	⊙

It is not yet possible to decide if the epochs of the last column satisfy better than Bessel's. I found the following observations of the disappearances and reappearances:

1848. First disappearance. (A.R. ♄ − A.R. ⊙ = $21^{h}\cdot5$.) No observations found.

First reappearance. (♄ − ⊙ = $12^{h}\cdot8$), Bond. Between August 31, 1878, and September 3·80, G.M.T. (*Monthly Notices*, vol. x. p. 17).

September 3, Schwabe: "no trace" (*Astronomische Nachrichten*, 665).

September 4, $9^{h}\cdot5$, Schwabe: sees the ring (6 f. telescope).

Julius Schmidt, at Bonn, sees the ring September 3 (heliometer and 5 f. telescope). (*Astronomische Nachrichten*, 648).

Busch, at Königsberg, September 5 (4-inch Plössl.), after cloudy weather (*Astronomische Nachrichten*, 658).

Galle, at Berlin, September 5, "zuerst im Refractor" (*Astronomische Nachrichten*, 647).

Dawes, September 1. Power 163. *No trace of the ring* (*Monthly Notices*, vol. x. p. 47).

September 2, 11^{h} G.M.T. Power 163. *The ring is visible* as an excessively narrow line *of nearly the same colour as the planet.*

* In the *Berliner Jahrbuch* of 1878, the elements of the ring of *Saturn* were omitted.

Second disappearance ($♄ - ☉ = 12^{h} \cdot 1$), Bond: between September 12·80 and 13·62 G.M.T. (l.c.) Schmidt sees the ring September 11, but saw it not September 14 at 8^h (*Astronomische Nachrichten*, 850). Busch: a trace September 13, no ring September 15 (*Astronomische Nachrichten*, 658). Schwabe: September 12 only the western ansa, the 13th no trace (*Astronomische Nachrichten*, 665).

Second reappearance 1849, January ($♄ - ☉ = 3^{h} \cdot 4$). Bond: between January 18·47 and 19·43 (l.c.). Schwabe: January 19 not visible, January 21 a thin line (*Astronomische Nachrichten*, 667). Schmidt: January 18 not, 21 well visible (*Astronomische Nachrichten*, 650).

1861. First disappearance ($♄ - ☉ = 19^{h} \cdot 6$). Secchi: the 23rd of November only a feeble line of light ("*un* faible trait de lumière"). (*Astronomische Nachrichten*, 1341.)

1862. First reappearance ($♄ - ☉ = 14^{h} \cdot 6$). Schwabe sees the ring (after long cloudy weather ? ?) for the first time 1862, February 7 (*Astronomische Nachrichten*, 1384).

Second disappearance ($♄ - ☉ = 7^{h} \cdot 5$). Dawes, May 17: Scarcely; no shadow of ring! (*Monthly Notices*, vol. xxii. p. 297.) Huggins saw the ring May 17, 18, and 19, and even 20, when the ansæ appeared "of a beautiful dark colour, scarcely distinguishable from the dark blue of the sky, which contrasted strongly with the yellow light of the ball."

Carpenter at Greenwich and O. Strüve (at Pulkowa?) saw the ring very well May 19, but also May 20, 25, and June 1; so I suppose it was the border of the ring that they saw, like also Huggins on May 20.

1878. $♄ - ☉ = 1^{h} \cdot 8$ at disappearance.
$= 0^{h} \cdot 9$ at reappearance.
No observations found.

1891. $♄ - ☉ = 23^{h} \cdot 5$ at disappearance.
$= 21^{h} \cdot 4$ at reappearance.

We see that in 1891 it will be impossible to observe the disappearance of the ring, but there is a chance left for the reappearance; the observations, however, must then be made before sunrise.

Utrecht: 1888, *December* 12.

Photographs of the Nebulæ M 31, *h* 44, *and h* 51 *Andromedæ, and M* 27 *Vulpeculæ.* By Isaac Roberts.

Nebulæ M 31, *h* 44, *and h* 51 *Andromedæ.*

The photograph* which accompanies these notes was taken on October 1 last, and it throws a very different light to that hitherto seen by astronomers upon the constitution of the great nebula, and we shall not exaggerate if we assert that it is now for the first time seen in an intelligible form.

No verbal description can add much to the information which the eye at a glance sees on the photograph, and those who accept the nebular hypothesis will be tempted to appeal to the constitution of this nebula for confirmation, if not for demonstration, of the hypothesis. Here we (apparently) see a new solar system in process of condensation from a nebula—the central sun is now seen in the midst of nebulous matter which in time will be either absorbed or further separated into rings. The farthest boundaries of the nebula have already separated into rings more or less symmetrical with the nucleus, and present a general resemblance to the rings of *Saturn.*

The two nebulæ *h* 44 and *h* 51 seem as though they were already undergoing their transformation into planets. But I must refrain from further running riot with the imagination and draw attention to some points shown upon the photograph, premising that we have now the means of keeping a strict watch upon many of the structural details of the nebula which in time may enable astronomers to arrive at a demonstration of the nebular hypothesis.

It will be observed that the nebula *h* 44 is shown on Bond's drawing with its major axis forming an angle of about 45° with a line joining its centre with the centre of *h* 51, whereas the photograph shows the axis to be pointed much more directly towards that nebula—the angle being less than 20°.

The difference is so obvious that we may reasonably suspect that it is not wholly due to error in charting but is indicative of a change in the direction of the axis since the year 1847, and some confirmation of this supposition is also given by comparison of the distances between the centres of the two nebulæ and the nucleus of the great nebula.

On Bond's chart the distance ratio of *h* 51 and *h* 44 with the nucleus is as 32 to 54, but on the photograph it is as 36 to 54, thus showing a large discrepancy.

M 27 *Vulpeculæ.*

The accompanying photograph of this nebula was taken on October 3 last, and shows more of the structure than the one with shorter exposure which was presented to the Society last year. It would be difficult to recognise in the photograph any resemblance to a dumb-bell, and only in general outline does it resemble the best drawings published of it.

* The photographs are deposited in the Library.

Height of a Leonid Fireball. By W. F. Denning.

A large meteor observed under nearly similar circumstances to those attending the Perseid fireball of August 13 last (*Monthly Notices*, 1888, November, p. 19) was recorded at Bristol and Sunderland on the night of November 13, at $17^h\ 19^m$.

The observations were as under :—

Bristol.—The writer recorded twenty-nine meteors between the hours of $15^h\ 30^m$ and 18^h (1888, November 13), and amongst this number there were seventeen which, by their directions and other features of appearance, conformed with the well-known stream of Leonids. The radiant point was in the usual position at $149° + 22°$, and three of the meteors were unusually large with apparent paths as follows:

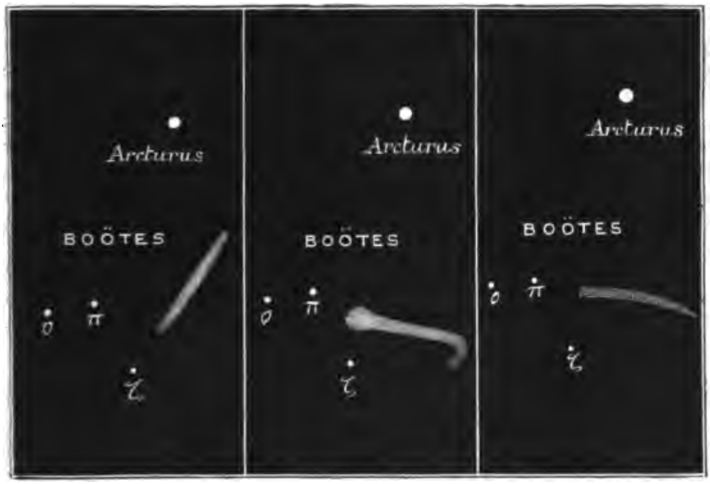
1888.	h m	Mag.	From	To	Appearance.
Nov. 13	16 41	♃	$166° + 34°$	$172° + 37\frac{1}{4}°$	V. swift, b. streak 5°
	16 55	Fireball	$125\frac{1}{2} - 22$	$121 - 30\frac{1}{2}$	V. b. flash, swift, stk. 10°
	17 19	♃	$252 + 33\frac{1}{2}$	$257\frac{1}{2} + 31$	Swift, streak 5°

The fireball at $16^h\ 55^m$ was a splendid object, though it appeared very low in the southern sky. The meteor at $17^h\ 19^m$ was also of considerable size, but its apparent brilliancy must have been greatly subdued by its situation in the mist immediately contiguous to the N.E. horizon. It appeared slightly N. of ϵ *Herculis* and its line of flight was sensibly parallel with ϵ and ζ *Herculis*.

Sunderland.—Mr. T. W. Backhouse was watching the progress of the Leonid shower on the same night. At $17^h\ 19^m$ he became suddenly aware of a bright flash and, a few seconds later, discovered an unusually intense meteor-streak lying amongst the stars of *Boötes* and about 5° below *Arcturus*. It was estimated as 4° long at first, and proved very durable, for it remained in sight during a period of nine minutes, during which it exhibited some alterations both in its shape and position. Mr. Backhouse was careful to notice the place of the streak directly after its first detection, when it extended from $213\frac{1}{2}° + 16\frac{1}{3}°$ to $217\frac{1}{4}° + 15°$, and he justly surmised it had been left by a Leonid fireball.

On comparing the pair of observations at $17^h\ 19^m$ it becomes obvious they relate to the same body, and that a satisfactory path can be derived from them. The radiant point is shown at $149° + 25°$ in the northern part of the sickle of *Leo*, which was in azimuth E. $50\frac{1}{2}°$ S. at the moment of the meteor's apparition. The heights of the beginning and end points of its path, observed at Bristol, were 65 and 37 miles respectively, and its central position was above a place in the North Sea, in about lat. $55\frac{1}{4}°$ N., long. $3\frac{3}{4}°$ E. The long enduring light streak visible

at Sunderland was nearly 15 miles in length, and the heights of its extremities were 57 and 45 miles. Its mean elevation was



$17^h\ 19^m$ $17^h\ 22\frac{1}{4}^m$ $17^h\ 28^m$

Streak of fireball, 1888, November 13, observed at Sunderland.

therefore 51 miles, which is but slightly less than that of the streak of the Perseid fireball before adverted to, and which indicated an average height of 53 miles. The length of the meteor's visible course was 34 miles, and its Earth-point was near lat. 55°·6 N., long. 3°·3 E. The duration of its flight was not estimated, so that its velocity cannot be determined. At Bristol, however, it was described as "swift," and the direct inference is that its motion probably accorded with the usual high rate of speed attributed to the Leonids.

Summarising the results we have:

Beginning of meteor (Bristol)	65 miles high
" " light streak (Sunderland)	57 "
End of light streak (Sunderland)...	45 "
End of meteor (Bristol)	37 "
Inclination to mean horizon	57°
Entire length of observed real path (Bristol) ...	34 miles.

The heights do not differ materially from the average of fireballs (*Monthly Notices*, 1888, January, p. 113), though the length of path is decidedly shorter than usual. But the meteor was at a great distance (more than 360 miles) from Bristol, and being

so close upon the horizon the conditions for glimpsing the fainter sections of its track were extremely unfavourable. It is certain that the low-lying vapours combined with the excessive distance in obliterating the streak which remained so persistent at Sunderland. The same effects were produced by similar causes in the case of the Perseid fireball, the streak of which endured at Leeds for three minutes, whereas at Bristol, the distance being greater and altitude of the object much less, it continued to be seen no longer than 40 secs. It will be interesting during future observations to compare the heights of the durable streaks which are so often generated by fireballs, and to further trace the effects of distance and altitude upon their visibility at different stations.

The diagram represents successive views of the streak left by the recent Leonid fireball. This feature had become very faint at $17^h\ 28^m$ (9 min. after first appearance), when it was just observable with an opera-glass, power 4.

Bristol: 1888, *December* 12.

The Great Southern Comet (1887 I). By Dr. H. Oppenheim.

(*Extract from a letter to Mr. Knobel.*)

Being at present occupied with a determination of the orbit of the great Southern Comet (1887 I), I have examined some observations made at sea by Captain Molony, which appeared in the *Monthly Notices*, vol. xlvii. p. 432.

As altogether only 19 observations of this Comet are known, earlier observations have great importance, as sextant observations have equal value with those of fixed instruments, which give distances to half a degree (*Astronomische Nachrichten*, Band 117, p. 13).

Captain Molony's observations as printed in the *Monthly Notices* appear, however, to be incorrect, as will be seen from the accompanying comparison. Would it be possible for you to make the observer acquainted with this, and inform me as to his reply? *

The following results are obtained from a comparison of the observations of Comet 1887 in the *Monthly Notices*, vol. xlvii. p. 432 (taking refraction into account) with the elements given in the *Astronomische Nachrichten*, 117, p. 13.

* Lieut. Baillie, of the Meteorological Office, has kindly compared the observations as printed in the *Monthly Notices* with Capt. Molony's meteorological log, and finds they have been correctly copied, so that the errors must rest with the observer.

1887, Jan. 21. Measured distance.		Obs.—Com. R.A. $\Delta\alpha$	Dec. $\Delta\delta$
Canopus—α Crucis	... ...	$-3^\circ\ 50'$	$+0^\circ\ 45'$
Canopus—Rigel ...	... ...	+3 0	+3 4
α Crucis—Rigel ...	... ...	+0 23	−0 24
January 22:			
Canopus—α Crucis	... ...	+0 31	+0 37
Canopus—α Arietis	... ...	+0 11	+0 30
α Arietis—α Crucis	... ...	−0 3	+0 46
January 25:			
Canopus—α Crucis	... ...	+2 27	+0 41
Canopus—Rigel ...	... ...	+1 11	+0 5
α Crucis—Rigel ...	... ...	+1 28	+0 51

From this it appears that the measured distance of the Comet from *Canopus* on January 21 and the measured distance from *α Crucis* on January 25 are incorrect. This is clear from the following:

Assuming the R.A. and Decl. of the Comet as known, from the ephemerides, and comparing the observed distances of the Comet from the stars, we obtain the following differences between computation and observation:

January 21:	Canopus	... ...	$+2^\circ\ 5'$
	α Crucis	... ...	−0 13
	Rigel	... ...	−0 14
January 22:	Canopus	... ...	+0 23
	α Crucis	... ...	+0 45
	α Arietis	... ...	−0 18
January 25:	Canopus	... ...	−0 19
	α Crucis	... ...	+1 4
	Rigel	... ...	−0 40

Berlin: 1888, *Dec.* 14.

Note on the Spectrum of Comet e 1888 (Barnard, September 2). By Dr. R. Copeland.

The spectrum was first examined on November 14. It presented a strange appearance, that at first sight was very puzzling, for instead of the feeble separate bands that usually characterise faint cometary spectra, the spectroscope revealed a rather long, continuous spectrum, extending from W.L. 575^{mmm} to W.L. 450^{mmm}, brighter in the middle and fading gradually away at both ends. It was, in fact, far more like that of a close globular cluster of stars, or a non-gaseous nebula, than of a mass of self-luminous gas. Owing to the spreading of the light over so great a part of the spectrum, a wide slit was imperatively necessary to permit of distinguishing any special features. Under this condition the spectrum seemed scarcely to differ from that of the zodiacal light or faint daylight, but on close scrutiny a soft, brighter patch of light was recorded at a point that turned out to have a W.L. of $510{\cdot}5^{mmm}$, and eventually an extremely feeble increase of light was detected at $476{\cdot}5^{mmm}$. These brighter patches probably represent the second and third cometary bands.

On November 26 similar observations were made, but with the addition that some traces of superposed brightness, indicative of the first band, were also distinguished. On December 5 the first and second bands only were measurable, but on the wonderfully clear night of December 8 all three bands were distinctly seen and recognised in and about the comet's nucleus. On each occasion the continuous spectrum already described formed the ground on which the brighter bands were superposed. The following summary shows the results of the measures, which were all made with the Grubb star-spectroscope and a simple prism of 60° angle.

Summary of Measures.

	Nov. 14.	No. of Obs.	Nov. 26.	No. of Obs.	Dec. 5.	No. of Obs.	Dec. 8.	No. of Obs.	Mean.	No. of Obs.
	mmm.		mmm.		mmm.		mmm.		mmm.	
Continuous spectrum between these limits. Spectrum begins	575		599	1	572	2	{588 574‡	1 1	580	6
1st band, 1st condensation	...	...	555·2	1	...	...	...	...	555·2	1
" middle of band seen as one	...	...	...	...	544·2	3	551·5‡	3	547·8	6
" 2nd condensation ...	...	...	535·6	1	...	...	...	...	535·6	1
2nd band, limit towards the red ...	...	...	517·9	4	...	...	519·8	5	519·0	9
" brightest part	510·5	1	515·0*	1	508·5	5	{514·0† 520·0‡	3 2	512·5	12
3rd band	476·5	1	478·8	1	...	...	472·6‡	3	474·6	5
Spectrum ends	450	1	453	1	461	2	459	1	455	5
Distance of comet from the Sun	2·065	...	1·998	...	1·953	...	1·940	...	...	...

* With a very wide slit, one large bright band was measured at 525·2^{mmm}, probably due to the superposition of the first and second bands on the continuous spectrum. Feeble traces of a second band were seen at 464^{mmm}.

† On the coma with a wide slit.

‡ Spectrum of nucleus.

From these measures it is evident that the bright bands are slowly developing under the continued action of the Sun's rays, and as the perihelion will not be reached until 1889, January 29·9, according to Dr. L. Becker's elements, they will probably become more obvious. Hitherto, however, far from the light being chiefly concentrated in these bands, nearly all the light has been spread out into a continuous spectrum, on which the bands are only seen with close attention. From this it seems probable that the comet shines mainly by reflected light (a question that the polariscope may perhaps decide), to which the action of the Sun on the cometary material is slowly adding the usual bright bands.

Lord Crawford's Observatory, Dun Echt:
1888, *December* 13.

Observations of Comets made at the Orwell Park Observatory in the years 1887–88. By John J. Plummer, M.A.

Comet V. 1887 (*Olbers–Brooks.*)

1887.	Greenwich Mean Time.	Comet–Star. Δα.	Comet–Star. Δδ.	No. of Comps.	Comet's App. R.A.	Log (p×Δ).	Comet's App. Dec.	Log (p×Δ).	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Sept. 12	15 31 57	+2 59·38	− 1 12·6	8–8	9 56 4·77	$9·6129_n$	+30 9 51·1	0·8208	+0·08	−7·7	1
Oct. 10	16 31 35	+1 57·67	+ 8 12·0	9–9	12 13 25·80	$9·6035_n$	+25 23 17·2	0·8108	+0·04	−5·3	2
12	16 5 31	−1 4·32	+ 3 6·4	8–8	12 22 43·50	$9·5939_n$	+24 47 3·3	0·8304	+0·04	−4·8	3
13	16 32 1	+2 2·32	+ 4 2·7	9–9	12 27 27·38	$9·6000_n$	+24 27 42·4	0·8146	+0·05	−4·9	4
17	16 55 5	+4 13·00	− 5 51·3	8–8	12 45 44·95	$9·5974_n$	+23 8 10·3	0·8053	+0·07	−4·6	5
19	16 42 43	−3 59·56	− 3 11·3	8–8	12 54 35·76	$9·5944_n$	+22 26 49·8	0·8156	+0·06	−3·8	6
21	16 30 12	−2 5·20	− 5 33·7	9–9	13 3 17·31	$9·5900_n$	+21 44 38·3	0·8252	+0·08	−3·7	7
25	17 3 12	+4 7·98	− 1 2·4	8–7	13 20 22·38	$9·5887_n$	+20 16 38·9	0·8111	+0·13	−3·7	8
28	16 42 58	−2 33·01	+ 0 3·3	8–8	13 32 36·75	$9·5847_n$	+19 9 51·7	0·8249	+0·14	−3·2	9
Nov. 4	17 1 55	−2 35·17	− 4 40·8	4–4	13 59 54·05	$9·5792_n$	+16 31 6·2	0·8218	+0·21	−2·2	10
6	17 10 13	+2 1·47	− 3 37·7	8–8	14 7 19·54	$9·5771_n$	+15 45 48·9	0·8197	+0·24	−2·3	11
14	17 9 36	+0 7·65	+ 2 35·6	6–6	14 35 23·40	$9·5709_n$	+12 48 23·4	0·8255	+0·34	−1·6	12
15	17 25 52	+3 4·12	− 9 37·7	7–7	14 38 45·54	$9·5670_n$	+12 26 0·9	0·8206	+0·35	−1·8	13
16	17 16 58	+5 44·87	− 4 2·3	6–6	14 42 3·09	$9·5684_n$	+12 4 46·9	0·8242	+0·37	−1·9	14

	Greenwich Mean Time.	Comet–Star. Δα.	Comet–Star. Δδ.	No. of Comps.	Comet's App. R.A.	Log (p×Δ).	Comet's App. Dec.	Log (p×Δ).	Red. to App. Place.		Comp. Star.
1887.	h m s	m s	′ ″		h m s		° ′ ″		s		
Dec. 6	17 33 49	+1 8·45	−10 12·2	9–9	15 40 57·31	9·5477n	+ 5 37 56·6	0·8306	+0·66	−0·7	15
8	17 27 27	−0 23·41	+ 5 44·6	6–6	15 46 10·42	9·5492n	+ 5 4 16·5	0·8324	+0·70	−0·5	16
10	17 36 4	+1 7·10	− 8 35·2	8–8	15 51 17·87	9·5429n	+ 4 31 18·9	0·8322	+0·73	−0·6	17
13	18 7 26	+3 1·60	+ 0 49·8	5–5	15 58 49·82	9·5156n	+ 3 43 36·3	0·8308	+0·78	−0·3	18
16	17 49 48	+1 5·47	+ 3 12·8	8–8	16 6 3·03	9·5265n	+ 2 58 12·2	0·8340	+0·84	−0·5	19
18	18 1 47	−2 17·55	− 0 33·9	8–8	16 10 46·61	9·5132n	+ 2 29 1·7	0·8345	+0·87	−0·3	20
27	18 0 47	+1 15·56	− 1 54·0	4–4	16 30 48·10	9·4979n	+ 0 28 46·4	0·8400	+1·04	−0·5	21
1888. Jan. 8	17 42 45	−0 48·58	− 2 51·8	8–8	16 54 44·46	9·4922n	− 1 45 45·5	0·8468	−1·84	+5·3	22
9	17 49 19	−4 3·28	− 8 47·7	8–8	16 56 37·24	9·4817n	− 1 56 0·4	0·8476	−1·83	+5·0	23
Feb. 10	17 12 40	−1 26·65	− 6 53·3	4–4	17 45 47·81	9·4227n	− 6 0 57·5	0·8633	−1·22	+1·0	24

Notes.

October 12.—Definition bad. October 13–19.—Comet faint from haze during the earlier comparisons.
October 17–25.—Comet faint owing to the coming daylight during the later comparisons.
November 4.—The observation was obtained with difficulty between clouds, and hence is rather doubtful.
November 14.—Observation interrupted by passing clouds. December 8.—Interrupted by clouds passing. Rather windy.
December 13.—Interrupted by clouds. Comet faint owing to the coming daylight during the later comparisons.
December 16.—Very windy; the clock heard with difficulty. December 27.—Interrupted by clouds passing.
January 8.—Comet rather faint. January 9.—Comet faint owing to fog and the coming dawn.
February 10.—The comet has become sensibly fainter since the last observation. Interrupted by clouds.

Comet I. 1888 (Sawerthal).

1888.		Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Comps.	Comet's App. R.A.	Log (p × Δ).	Comet's App. Dec.	Log (p × Δ).	Red. to App. Place.		Comp. Star.
		h m s	m s	′ ″		h m s		° ′ ″		s	″	
April	3	15 56 34	−0 59·58	− 5 30·3	3–3	22 9 24·31	9·5554n	+ 5 58 46·8	0·8323	−0·99	− 7·5	25
	3	16 9 34	−5 55·23	− 2 11·3	1–1	22 9 26·38	9·5499n	+ 5 59 21·3	0·8304	−1·01	− 7·6	26
	4	15 53 24	+4 17·65	− 9 24·0	7–7	22 12 25·81	9·5570n	+ 7 0 8·7	0·8307	−0·96	− 7·7	27
	11	15 38 21	−1 0·39	− 3 6·3	9–8	22 33 4·22	9·5685n	+13 31 23·0	0·8172	−0·89	− 9·1	28
	18	15 19 29	+3 6·75	+ 4 42·5	7–7	22 52 38·17	9·5833n	+19 2 23·3	0·8054	−0·79	−10·0	29
	20	15 13 21	+0 25·07	+ 8 27·5	8–8	22 58 0·54	9·5878n	+20 27 18·4	0·8028	−0·78	−10·2	30
May	1	15 2 48	+4 6·05	− 0 12·9	6–6	23 25 49·60	9·6095n	+27 12 27·8	0·7721	−0·61	−11·3	31
	5	14 37 55	+1 50·59	− 8 57·7	7–7	23 35 8·75	9·6202n	+29 17 20·6	0·7777	−0·56	−11·6	32
	7	13 49 51	+2 45·79	− 5 36·1	8–8	23 39 35·66	9·6181n	+30 15 32·3	0·8109	−0·53	−11·7	33
	8	13 48 28	−1 45·49	− 2 15·5	8–8	23 41 49·34	9·6203n	+30 44 9·9	0·8090	−0·54	−11·7	34
	10	13 48 20	−1 19·08	− 6 57·3	9–9	23 46 10·54	9·6257n	+31 39 58·5	0·8031	−0·50	−11·8	35
	11	13 39 20	+1 26·67	− 1 30·5	8–8	23 48 19·12	9·6254n	+32 6 58·1	0·8077	−0·47	−11·8	36
	12	13 45 43	+3 10·86	− 2 57·0	9–9	23 50 26·95	9·6302n	+32 33 34·7	0·7991	−0·44	−11·9	37
	13	13 24 25	+3 50·02	+ 1 35·0	8–8	23 52 31·21	9·6251n	+32 59 41·2	0·8144	−0·42	−11·9	38
	13	13 30 52	+2 5·75	+ 8 3·8	6–6	23 52 31·52	9·6279n	+32 59 45·7	0·8089	−0·43	−11·9	39
	23	11 58 55	+4 53·92	− 7 14·1	7–7	0 11 54·69	9·5959n	+36 56 48·9	0·8566	−0·22	−12·2	40
	26	11 25 24	−0 53·64	+ 3 36·1	9–9	0 17 13·29	9·5682n	+38 0 50·5	0·8744	−0·19	−12·2	41
	27	11 33 25	−3 41·45	− 6 23·6	8–8	0 18 57·52	9·5842n	+38 21 37·0	0·8662	−0·18	−12·3	42

1888.		Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Comps.	Comet's App. R.A.	Log (p×Δ).	Comet's App. Dec.	Log (p×Δ).	Red. to App. Place.		Comp Star
		h m s	m s	′ ″		h m s		° ′ ″		s	″	
May	30	11 18 45	−3 31·07	− 6 49·1	8–8	0 23 58·16	$9·5797_n$	+39 22 12·7	0·8699	−0·11	−12·3	43
	31	11 21 13	+3 10·84	+ 2 33·8	8–8	0 25 36·01	$9·5882_n$	+39 42 7·0	0·8658	−0·04	−12·3	44
June	3	12 47 32	+1 26·45	− 4 36·4	9–9	0 30 24·23	$9·6721_n$	+40 40 26·9	0·7767	−0·02	−12·3	45
	6	11 8 48	−2 54·33	− 5 35·4	8–8	0 34 45·59	$9·6030_n$	+41 34 16·1	0·8600	+0·07	−12·3	46
	13	11 34 20	−1 20·14	+ 4 43·1	8–8	0 41 34·20	$9·6656_n$	+43 35 50·8	0·8122	+0·30	−12·1	47
July	3	12 7 28	−1 17·24	− 3 42·6	9–9	1 3 2·25	$9·7397_n$	+48 30 10·0	0·6642	+0·99	−11·3	48
Aug.	8	11 28 15	−1 12·40	+ 1 21·7	8–8	0 59 39·80	$9·7484_n$	+54 23 29·5	0·3180	+2·66	− 5·2	49
	10	11 12 20	−1 55·19	− 4 21·5	5–5	0 57 51·09	$9·7562_n$	+54 34 42·8	0·3351	+2·76	− 4·7	50

Notes.

April 3.—Passing clouds. April 18.—Sky rather hazy. April 20.—Foggy, cloudy at times: comet rather faint in consequence.

May 5.—Comet rather fainter than expected (this is the first indication of variability of brightness noted).

May 12.—Sky hazy and the comet fainter in consequence.

May 23.—Sky very clear. Comet brighter than expected. This increase of brilliancy is noted by Dr. Schwarz, in Dorpat. (See *A.N.* 2842) and others.

May 27.—Comet fainter; sky hazy. May 30.—Windy; clock difficult to follow at times.

May 31–June 13.—The comparisons in R.A. are difficult and rather uncertain owing to the elongated form of the nucleus of the comet in the direction of the parallel of declination.

June 3.—Sky hazy. Observation scarcely satisfactory. June 6.—Comet faint, owing to fog.

July 3.—Comet much fainter than when last seen and difficult to observe with accuracy.

Aug. 8.—Comet very faint and the coma has almost disappeared. Nucleus small and starlike. On Aug. 2 the nucleus was indeed thought to be a small star within the coma, and no observation was then taken, as it was considered that such observation would be that of a star and would not accurately represent the place of the comet.

Assumed Mean Places of Comparison Stars.

Comet V. 1887.

Comp. Star.	R.A. 1887·0.	Decl. 1887·0.	Authority.
	h m s	° ′ ″	
1	9 53 5·31	+30 11 11·4	¼ (Gr. 9 yr. 949 + Gr. 7 yr. 1221 + Yarn. 4162 + Arm.₁ 2180).
2	12 11 28·09	+25 15 10·5	B.W.₂ 193. The R.A. of Lal. 23011, which is the same star, is 1ˢ·28 less.
3	12 23 47·78	+24 44 1·7	18 *Comæ* ⅓ (2 Arm.₁ 2684 + Lal. 23357).
4	12 25 25·01	+24 23 44·6	½ (Yarn. 5217 + B.W.₂ 500–1).
5	12 41 31·88	+23 14 6·1	B.W.₂ 822.
6	12 58 35·26	+22 30 5·0	B.W.₂ 1124.
7	13 5 22·43	+21 50 15·8	½ (Arm.₂ 1531 + B.W.₂ 45–6). The declination of Arm.₂ 1531 is about 1′ less; that of Weisse is confirmed by Lal. 24505, the same star with an erroneous R.A.
8	13 16 14·27	+20 17 45·0	Equat. comparison with Arm.₁ 2838
9	13 35 9·63	+19 9 51·6	B.W.₂ 676–7.
10	14 2 29·01	+16 35 49·2	B.W.₂ 1341.
11	14 5 17·83	+15 49 29·0	½ (B.W.₂ 61 + Lal. 26005).
12	14 35 15·41	+12 45 49·4	⅓ (2 Glasg. 3625 + B.W.₁ 619).
13	14 35 41·07	+12 35 40·3	⅓ (2 Glasg. 3631 + B.W.₁ 628).
14	14 36 17·84	+12 8 51·1	32 *Boötis* ¼ (Glasg. 3635 + Arm.₁ 3101 + B.W.₁ 638 + Lal. 26777). The proper motion of this star from a comparison of the above catalogues, and Bradley 1879 appears to be −0ˢ·011 in R.A. and −0″·145 in decl.
15	15 39 48·19	+ 5 48 9·5	⅓ (2 Arm.₂ 1837 + Lal. 28716).
16	15 46 33·13	+ 4 58 32·5	½ (Lam. 1850 + Equat. comparison with *ε Serpentis*).
17	15 50 10·04	+ 4 39 54·7	¼ (2 Glasg. 3919 + B.W.₁ 922 + Lal. 28995–6).
18	16 1 50·64	+ 3 42 46·8	⅓ (Glasg. 3968 + Arm.₂ 1887 + Lam. 1943). This star has possibly proper motion in declination only. None, however, is assumed.
19	16 4 56·72	+ 2 55 0·0	½ (Glasg. 3987 + Arm.₂ 1895).
20	16 13 3·29	+ 2 29 35·8	B.B. vi. + 2° 3076.
21	16 29 31·50	+ 0 30 40·9	½ (Lam. 5205 + Equat. comparison with Glasg. 4093).
	1888·0.	1888·0.	
22	16 55 34·88	− 1 42 59·0	¼ (Lam. 5433 + B.W.₁ 1017 + Schj. 6055 + Equat. comparison with Glasg. 4217).
23	17 0 42·35	− 1 47 17·7	B.B. vi.−1° 3294.
24	17 47 15·68	− 5 54 5·3	¼ (B.W.₁ 917 + Lam. 2491 + Arm.₂ 2119 + Cord. Zones).

Comet I. 1888.

Comp. Star.	R.A. 1887·0. h m s	Decl. 1887·0. ° ′ ″	Authority.
25	22 10 24·88	+ 6 4 24·7	Schj. 9094.
26	22 15 22·62	+ 6 1 40·3	$\frac{1}{3}$ (2 Glasg. 5791 + B.W.₁ 271).
27	22 8 9·12	+ 7 9 40·4	$\frac{1}{4}$ (2 Glasg. 5741 + B.W.₁ 114 + Lal. 43361–2).
28	22 34 5·50	+13 34 38·4	$\frac{1}{2}$ (Lam. 3147 + B.W.₁ 688).
29	22 49 32·21	+18 57 50·7	$\frac{1}{3}$ (Lam. 1728 + B.W.₂ 1109 + Lal. 44837).
30	22 57 36·25	+20 19 1·1	$\frac{1}{3}$ (2 Arm.₂ 3116 + B.W.₂ 1279).
31	23 21 44·16	+27 12 52·0	Equat. comparison with B.W.₂ 296 and B.W.₂ 384.
32	23 33 18·73	+29 26 29·8	B.W.₂ 692.
33	23 36 50·40	+30 21 20·1	B.W.₂ 777–8.
34	23 43 35·37	+30 46 37·1	Equat. comparison with B.W.₂ 860 and B.W.₂ 991.
35	23 47 30·12	+31 47 7·6	Lal. 46809.
36	23 46 52·92	+32 8 40·5	A.N. 2861 (Leiden A. G. Zones 118–123).
37	23 47 16·53	+32 36 43·6	B.W.₂ 966.
38	23 48 41·61	+32 58 18·1	$\frac{1}{2}$ (B.W.₂ 989 + Lal. 46847).
39	23 50 26·20	+32 51 53·8	$\frac{1}{4}$ (2 Arm.₂ 3270 + B.W.₂ 1020 + Lal. 46911–2). The R.A of Bessel appears to be 1ˢ too great. It has been diminished accordantly.
40	0 7 0·98	+37 4 15·2	$\frac{1}{2}$ (Yarn. 59 + Paris Observations).
41	0 18 7·12	+37 57 26·6	R *Andromedæ*, B.B. vi. + 37°·58.
42	0 22 39·16	+38 28 12·9	$\frac{1}{2}$ (B.W.₂ 530 + Lal. 618).
43	0 27 29·34	+39 29 14·1	$\frac{1}{4}$ (2 Arm.₂ 81 + B.W.₂ 656–7 + Lal. 788–9).
44	0 22 25·21	+39 39 45·5	$\frac{1}{2}$ (B.W.₂ 524 + Lal. 606).
45	0 28 57·76	+40 45 15·5	$\frac{1}{2}$ (B.W.₂ 689 + Lal. 836).
46	0 37 39·85	+41 40 3·7	Equat. comparison with B.B. vi. + 41°·126.
47	0 42 54·04	+43 31 19·8	$\frac{1}{2}$ (B.W.₂ 1058 + Lal. 1303).
48	1 4 18·50	+48 34 3·9	$\frac{1}{2}$ (Radc.₁ 356 + Arg. Oe.₁ 1181).
49	1 0 49·54	+54 22 12·9	μ *Cassiopeiæ* $\frac{1}{3}$ (Gr. 9 yr. 103 + Yarn. 565 + Radc.₁ 329).
50	0 59 43·52	+54 39 9·1	Equat. comparison with θ *Cassiopeiæ* and Radc.₁ 334.

Col. Tomline's Observatory, Orwell Park:
1888, *November* 23.

Observations of Comets a 1888 (Sawerthal), and e 1888 (Barnard), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East or Sheepshanks equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

Comet a 1888 (Sawerthal).

Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Refraction Par.	Corr. for Refraction Refraction	☄−✱' N.P.D.	Corr. for Refraction Par.	Corr. for Refraction Refraction	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star
1888. d h m s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
June 8 10 59 11	T.	−0 17·12	−0·20	0·00	− 3 6·3	−3·8	−0·5	8	...	...	*a*
11 5 42	...	+1 33·75	−0·20	0·00	+ 4 34·9	−3·7	+0·8	2	...	...	*b*
11 7 43	...	+1 31·50	−0·20	0·00	+ 2 52·2	−3·7	+0·5	1	0 37 34·50	47 49 44·1	*c*
9 11 13 12	H.	−4 15·68	−0·20	0·00	− 4 38·2	−3·6	−0·6	4	0 38 57·03	47 32 29·3	*d*
11 11 36 41	T.	−0 31·50	−0·20	0·00	+ 2 11·5	−3·4	+0·2	2	...	...	*e*
28 11 15 53	A. D.	+0 11·17	−0·20	0·00	−12 1·3	−2·9	−0·6	3	0 59 24·77	42 37 16·9	*f*
11 27 19	...	−1 22·56	−0·22	0·00	+ 4 40·7	−2·8	+0·2	5	0 59 31·62	42 37 29·4	*g*
July 10 12 12 16	H.	+0 16·55	−0·30	0·00	− 2 0·2	−2·5	−0·1	2	1 6 10·45	40 2 32·2	*h*
12 24 51	...	−0 20·80	−0·30	0·00	+ 1 14·8	−2·5	0·0	1	...	...	*i*

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1880·0.	N.P.D., 1880·0.	Authority.
		h m s	° ′ ″	
a	Arg. Zone + 41°, No. 120	0 37 52	47 54	Bonn Observations, vol. v.
b	Arg. Zone + 42°, No. 151	0 36 2	47 46	" " "
c	Arg. Zone + 42°, No. 152	0 36 3·04	47 46 42·9	" " vol. vi.
d	Arg. Zone + 42°, No. 181	0 43 12·74	47 36 59·5	" " "
e	Arg. Zone + 42°, No. 174	0 42 10	46 56	" " vol. v.
f	Oeltz. Arg. (N.) 1075	0 59 12·96	42 49 23·2	Oeltz. Arg. (N)
g	Oeltz. Arg. (N.) 1111	1 0 53·65	42 32 39·7	" "
h	Arg. Zone + 49°, No. 322	1 5 52·91	40 4 24·4	Bonn Observations, vol. vi.
i	Arg. Zone + 49°, No. 324	1 6 35	40 1	" " vol. v.

Notes.

June 8.—Comet very faint. June 11.—Comet very faint indeed. Cloudy.
June 28.—Comet with stellar nucleus (about as bright as a 10th magnitude star) and straight tail, which is traceable for about 6′.
July 10.—Comet was only a very faint patch of light. No perceptible nucleus.

The observations are corrected for parallax and refraction.
The initials A.D., T., and H., are those of Mr. Downing, Mr. Thackeray, and Mr. Hollis, respectively.

Comet e 1888 (*Barnard*).

Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Refraction Par.	Corr. for Refraction	☄−✱ N.P.D.	Corr. for Refraction Par.	Corr. for Refraction	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1888. d h m s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
Nov. 26 8 6 41	L.	−0 18·68	−0·20	0·00	+0 51·1	−6·6	+0·1	6	...	...	*a*
8 27 11	...	−0 31·72	−0·20	0·00	+5 51·7	−6·6	+0·4	6	...	...	*b*
27 8 44 8	H. T.	−0 16·27	−0·10	0·00	+5 39·7	−6·6	+0·4	3	2 42 32·23	95 26 0·7	*c*
8 47 6	...	+2 3·53	−0·10	0·00	+0 37·5	−6·6	0·0	4	2 42 30·33	95 26 6·5	*d*
Dec. 11 9 42 25	H.	−0 31·40	+0·10	0·00	−4 14·7	−5·8	−0·3	2	1 22 16·30	97 28 59·3	*e*
9 58 57	...	−1 17·93	+0·10	0·00	+3 36·1	−5·8	+0·3	3	1 22 13·67	97 28 50·7	*f*
12 6 41 5	T.	−0 24·58	−0·10	0·00	+2 15·1	−5·7	+0·1	6	1 18 20·42	97 31 58·3	*g*
6 41 5	...	−0 52 5	−0·10	0·00	−1 51·6	−5·7	−0·1	6	1 18 20·70	97 31 58·6	*h*

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1880·0.	N.P.D., 1880·0.	Authority.
		h m s	° ′ ″	
a	Schönfeld's Zones − 5°·540	2 48 44	95 17	Bonn Observations, vol. viii.
b	Schönfeld's Zones − 4°·494	2 48 58	95 8	" " "
c	W. B., II., 707	2 42 45·71	95 20 32·4	Weisse's Bessel.
d	W. B., II., 666	2 40 24·01	95 25 44·2	Paris Catalogue, 1875.
e	W. B., I., 352	1 22 45·10	97 33 29·2	Weisse's Bessel.
f	W. B., I., 563	1 23 28·97	97 25 39·3	Bonn Observations, vol. vi.
g	W. B., I., 271	1 18 42·63	97 29 58·8	Paris Catalogue, 1845.
h	W. B., I., 283	1 19 10·77	97 34 5·1	Weisse's Bessel.

Notes.

Nov. 26.—Comet has very bright nucleus. The envelope extends half way to star *a*.
Dec. 11.—Comet very faint. Bright moonlight and mist. Dec. 12.—Comet very faint indeed. Bright moonlight.

The observations are corrected for parallax and refraction.

The initials H.T., T., L., and H., are those of Mr. Turner, Mr. Thackeray, Mr. Lewis, and Mr. Hollis, respectively.

Observations of Comet e 1888 with the Transit Circle.

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D. (corrected for Refraction and Parallax).	Remarks.
1888. d h m s		h m s	° ′ ″	
Nov. 27 10 13 6	T.	2 42 6·12	95 26 56·79	Cloudy. Observed in dark field with wires illuminated.
Dec. 1 9 31 43	T.	2 16 22·40	96 17 48·42	Very faint indeed. Observed in dark field with wires illuminated.
5 8 52 35	H.	1 52 53·78	96 55 12·50	Dark field. The comet was faint and the illuminated wires hardly visible. The observation is therefore very rough.
7 8 33 58	L.	1 42 6·75	97 9 6·48	
12 7 50 21	A. D.	1 18 5·75	97 31 54·80	Very uncertain observation. Illuminated wires not visible, owing to strong moonlight.

The initials A.D., T., L., and H., are those of Mr. Downing, Mr. Thackeray, Mr. Lewis, and Mr. Hollis, respectively.

Observations of Comet Barnard (1888, September 2) made at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, F.R.S., Radcliffe Observer.*)

The following observations were made with the Barclay equatorial, using the ring-micrometer, with power 100.

1888.	G.M.T.	Local Sidereal Time.	Observer.	Comet—Star (Corrected for Refraction only.) R.A.	Comet—Star N.P.D.	No. of Comparisons.	Apparent R.A. of Comet.	Parallax in R.A. / p	Log	Apparent N.P.D. of Comet.	Parallax in N.P.D. / q	Log q Δ.	Reference to Comparison Star.
	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Oct. 5	14 17 7	3 12 47	R.	+1 28·34	+3 21·36	7	6 34 16·04	0·142	9·4533	81 59 5·0	3·17	0·8029	(a)
Nov. 13	13 13 55	4 43 10	R.	−0 31·05	−5 7·83	12	4 17 9·42	0·036	8·6152	91 8 35·3	6·20	0·8459	(b)

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent R.A.	Mean N.P.D. 1888·0.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(a)	6 32 46·13	+1·57	81 55 44·03	−0·42	Transit Circle Observation, 1888, December 12.
(b)	4 17 37·55	+2·92	91 13 49·30	−6·17	Mean of Göttingen, 1875, Nos. 1164 and 1165.

Mr. Robinson's Remarks.

October 5.—Circular Nebulosity, about 3½′ diameter. Distinct nucleus of the 10th magnitude.

In the computations of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85 and the geocentric distances, Δ, have been taken from the *Astronomische Nachrichten*, Nos. 2858, p. 32, and 2861, p. 80.

At $13^h\ 29^m\ 10^s{\cdot}0$ G.M.T. of November 13, or Local Sidereal Time $4^h\ 58^m\ 27^s{\cdot}6$, a star of the 10th magnitude appeared to be occulted by the nucleus of the comet, which was estimated to be of the same brightness as the star. The R.A. and N.P.D. of the star obtained from three independent sets of comparisons with the star (*b*) on November 13, December 12, and December 22 are :—

		Correction for Reduction to Appar. R.A.		Correction for Reduction to Appar. N.P.D.
	h m s	s	° ′ ″	″
Epoch 1888·0	4 17 2·49	+2·92	91 8 49·9	−6·17

This would give the following places for the comet at the time of occultation:

Apparent R.A. of Comet.	Parallax in R.A. p	Apparent N.P.D. of Comet.	Parallax in N.P.D. q	Observer.
h m s	s	° ′ ″	″	
4 17 5·41	+0·06	91 8 43·7	−6·20	Mr. Robinson

The calculated motion between the observations with the ring-micrometer and the time of occultation, as given by the ephemeris, is $-4^s{\cdot}09$ in R.A. and $+13''{\cdot}10$ in N.P.D.

In the observations of Sawerthal's Comet, printed in the *Monthly Notices* for May, June, and November 1888, the logarithms of the parallaxes in R.A. and N.P.D. have been given under the headings $\log p \times \Delta$, computed with an adopted value of the Sun's mean distance equal to $8''{\cdot}85$, and geocentric distances extracted from the ephemerides of the *Astronomische Nachrichten*, Nos. 2834, 2835, 2838, 2846. The symbol p does not therefore, in these results, denote the parallax in R.A. and N.P.D. respectively, but the factors which, when multiplied by Δ, give the required parallaxes.

Radcliffe Observatory, Oxford :
1888, *December* 14.

Ephemeris for Physical Observations

Greenwich Noon.		Angle of Position of ♃'s Axis.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax. A−L.	L−O.	Longitude of ♃'s Central Meridian. (877°·90) I.	Longitude of ♃'s Central Meridian. (870°·27) II.	Corr. for Phase.
1889.		°	°				°	°	°
Feb.	26	357·492	−2·245	−2·404	−9·777	138·269	240·18	237·43	+0·42
Mar.	3	357·147	2·228	2·391	10·116	139·012	309·31	268·41	·45
	8	356·827	2·211	2·377	10·401	139·702	18·51	299·45	·47
	13	356·534	2·195	2·363	10·630	140·336	87·77	330·56	·49
	18	356·268	2·180	2·349	10·800	140·910	157·10	1·74	·51
	23	356·031	2·166	2·335	10·907	141·422	226·50	32·98	·52
	28	355·825	2·153	2·321	10·948	141·869	295·96	64·29	·52
Apr.	2	355·652	−2·141	−2·307	−10·919	142·246	5·49	95·67	+0·52
	7	355·512	2·130	2·293	10·818	142·551	75·09	127·11	·51
	12	355·406	2·120	2·278	10·643	142·782	144·76	158·62	·49
	17	355·334	2·112	2·263	10·391	142·937	214·49	190·21	·47
	22	355·298	2·105	2·249	10·061	143·014	284·29	221·86	·44
	27	355·299	2·099	2·234	9·653	143·013	354·16	253·57	·41
May	2	355·335	−2·094	−2·219	−9·165	142·933	64·09	285·35	+0·37
	7	355·407	2·091	2·204	8·600	142·775	134·08	317·18	·32
	12	355·514	2·088	2·188	7·959	142·541	204·12	349·06	·28
	17	355·654	2·086	2·173	7·245	142·235	274·21	21·00	·23
	22	355·826	2·085	2·157	6·462	141·861	344·34	52·98	·18
	27	356·028	2·085	2·142	5·615	141·423	54·50	84·99	·14
June	1	356·256	−2·085	−2·126	−4·711	140·928	124·69	117·03	+0·10
	6	356·507	2·085	2·110	3·758	140·384	194·90	149·09	·06
	11	356·777	2·085	2·094	2·765	139·801	265·11	181·15	·03
	16	357·061	2·086	2·078	1·743	139·188	335·32	213·20	·01
	21	357·354	2·086	2·062	−0·701	138·556	45·50	245·23	
	26	357·652	2·085	2·045	+0·350	137·915	115·65	277·24	
July	1	357·949	−2·084	−2·029	1·398	137·278	185·76	309·21	−0·01
	6	358·239	2·082	2·012	2·432	136·655	255·83	341·12	·03
	11	358·518	2·079	1·996	3·440	136·058	325·84	12·97	·05
	16	358·780	2·076	1·979	4·413	135·496	35·77	44·76	·08
	21	359·021	2·071	1·962	5·342	134·979	105·62	76·46	·12
	26	359·238	2·066	1·945	6·218	134·515	175·39	108·08	·17
	31	359·427	2·060	1·928	7·033	134·112	245·07	139·61	·22
Aug.	5	359·584	−2·053	−1·911	+7·782	133·775	314·65	171·04	−0·26
	10	359·708	2·045	1·893	8·460	133·510	24·13	202·38	·31

of Jupiter, 1889. By A. Marth.

Greenwich Noon.	Diameter Equat.	Polar	Difference of limbs in A.R.	in Decl.	Defect of illumination. Equat.	in A.R. preceding limb.	d	w
1889 Feb. 26	34·79″	32·58″	2·521s	32·59″	0·25″	0·018s	9·77°	271·21°
Mar. 3	35·26	33·02	2·555	33·03	·27	·020	10·11	·20
8	35·75	33·48	2·590	33·49	·29	·021	10·39	·20
13	36·27	33·97	2·627	33·98	·31	·022	10·62	·19
18	36·82	34·48	2·666	34·49	·33	·024	10·79	·19
23	37·39	35·00	2·706	35·02	·34	·024	10·90	·18
28	37·97	35·55	2·748	35·57	·34	·025	10·94	·17
Apr. 2	38·57	36·12	2·792	36·14	0·35	0·025	10·91	271·16
7	39·19	36·70	2·836	36·71	·35	·025	10·81	·14
12	39·82	37·29	2·881	37·30	·34	·025	10·63	·12
17	40·46	37·88	2·927	37·90	·33	·024	10·38	·10
22	41·10	38·48	2·973	38·50	·31	·023	10·05	·08
27	41·73	39·07	3·019	39·10	·29	·021	9·65	·05
May 2	42·35	39·65	3·064	39·68	0·27	0·019	9·16	271·02
7	42·96	40·22	3·109	40·24	·24	·017	8·59	270·98
12	43·54	40·77	3·152	40·79	·21	·015	7·95	270·93
17	44·09	41·28	3·192	41·30	·18	·013	7·24	270·88
22	44·60	41·76	3·230	41·78	·14	·011	6·46	270·82
27	45·06	42·19	3·264	42·21	·11	·008	5·61	270·73
June 1	45·46	42·57	3·294	42·59	0·08	0·006	4·71	270·62
6	45·80	42·89	3·319	42·90	·05	·004	3·75	270·49
11	46·07	43·14	3·340	43·15	·03	·002	2·76	270·26
16	46·27	43·32	3·355	43·33	·01	·001	1·74	269·7
21	46·39	43·43	3·365	43·44	on following		0·70	268·0
26	46·42	43·47	3·368	43·47	limb		0·35	97·0
July 1	46·37	43·43	3·365	43·43			1·40	92·4
6	46·25	43·31	3·357	does	0·02	0·002	2·43	91·71
11	46·05	43·12	3·343	not	·04	·003	3·44	91·41
16	45·77	42·86	3·323	differ	·07	·005	4·41	91·26
21	45·43	42·54	3·298	from	·10	·007	5·34	91·15
26	45·02	42·16	3·269	polar	·13	·010	6·21	91·07
31	44·56	41·73	3·236	diameter	·17	·012	7·03	91·01
Aug. 5	44·06	41·26	3·200		0·20	0·015	7·78	90·97
10	43·52	40·75	3·161		·24	·017	8·46	·94

Greenwich Noon.		Angle of Position of ♃'s Axis.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax. A−L.	L−O.	Longitude of ♃'s Central Meridian. (877°·90) I.	Longitude of ♃'s Central Meridian. (870°·27) II.	Corr. for Phase.
1889.									
Aug.	15	359°·797	2°·036	1·876	9·064	133·320	93°·52	233°·62	°·36
	20	359·850	2·026	1·858	9·591	133·207	162·81	264·77	·40
	25	359·866	2·015	1·840	10·040	133·171	232·01	295·82	·44
	30	359·845	2·004	1·823	10·410	133·215	301·11	326·77	·47
Sept.	4	359·788	−1·992	−1·805	+10·702	133·338	10·12	357·64	−0·50
	9	359·694	1·979	1·787	10·917	133·538	79·05	28·42	·52
	14	359·565	1·965	1·769	11·057	133·813	147·89	59·11	·53
	19	359·402	1·950	1·750	11·123	134·161	216·66	89·73	·54
	24	359·206	1·935	1·732	11·119	134·581	285·35	120·28	·54
	29	358·977	1·919	1·714	11·047	135·069	353·97	150·76	·53
Oct.	4	358·718	−1·902	−1·695	+10·910	135·622	62·54	181·17	−0·52
	9	358·430	1·883	1·676	10·712	136·237	131·05	211·53	·50
	14	358·116	1·864	1·658	10·455	136·909	199·50	241·84	·48
	19	357·776	1·844	1·639	10·144	137·636	267·91	272·10	·45
	24	357·412	−1·823	−1·620	+9·782	138·416	336·29	302·33	0·42

The angle A—L is the difference of the Jovicentric longitudes of the Sun and Earth, reckoned in the plane of *Jupiter's* equator; L−O+180° the Jovicentric longitude of the Earth reckoned from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or the point of the ascending node of the planet's orbit on its equator.

Two values of the "longitude of ♃'s central meridian" are given for each date: the first, computed with the daily rate of rotation 877°·90, being intended for comparing the observations of white spots in the neighbourhood of the planet's equator; the second, computed with the rate 870°·27, for the observations of the remnant of the great reddish spot in the planet's southern hemisphere. This latter rate is the same as that adopted in the ephemerides for the two preceding oppositions, but the zero-meridian has been put back 10° or the longitudes in the present ephemeris have been increased 10°, in order that the zero-meridian may precede the middle of the spot, at least in case the rate of the spot's motion does not become sensibly accelerated. The daily rate 877°·90 of system I is approximately that of the motion of two bright spots, observed during the past apparition of *Jupiter* at Brighton by Mr. A. S. Williams, who has been good enough to communicate his observations to me, the only ones which have yet come to my knowledge. His few observations of an equatorial spot procured in 1887 seem to belong to one of these spots. But the irregularity and uncertainty of the motion, and the want of sufficient observations between 1885 and 1887 render it, for the present at least, not feasible to establish the

Greenwich Noon.	Diameter Equat.	Diameter Polar	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat.	Defect of illumination. in A.R. preceding limb.	d	w
1889	″	″	s		″	s	°	°
Aug. 15	42·95	40·22	3·120		·27	·019	9·06	·91
20	42·36	39·66	3·077		·30	·021	9·59	·89
25	41·75	39·09	3·033		·32	·023	10·03	·88
30	41·13	38·52	2·989		·34	·025	10·41	·88
Sept. 4	40·52	37·94	2·944		0·35	0·026	10·70	90·88
9	39·91	37·37	2·900		·36	·026	10·91	·88
14	39·30	36·80	2·856		·36	·026	11·05	·89
19	38·71	36·24	2·813		·36	·026	11·12	·90
24	38·13	35·70	2·772		·36	·026	11·11	·92
29	37·57	35·18	2·731		·35	·025	11·04	·95
Oct. 4	37·03	34·67	2·692		0·33	0·024	10·91	90·98
9	36·51	34·19	2·655		·32	·023	10·71	91·00
14	36·02	33·73	2·619		·30	·022	10·45	91·03
19	35·55	33·29	2·585		·28	·020	10·14	91·07
24	35·11	32·88	2·552		·26	0·019	9·78	91·11

connection between these spots and the chief white spot, observed from 1880 to 1886, especially assiduously by Mr. Denning at Bristol.—The differences of successive values of the longitudes of ♃'s central meridian amount, for the interval of five days, to twelve rotations in addition to the differences directly deduced, so that, for instance, the differences of the first two values are 4389°·13 and 4350°·98. The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc. A list of Greenwich times when these latter longitudes are 0° is given further on.

The diameters of the disc, &c., depend on the same assumed values as in the ephemerides for preceding years. The formulæ employed may be found in vol. xlv. p. 508.

The inclinations γ and the ascending nodes Γ of the orbits of the four satellites of *Jupiter* in reference to the assumed plane of the planet's equator are the following, the longitudes of the nodes being reckoned from O, the point of the ascending node of *Jupiter's* orbit on the equator:

	Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
	γ_1	Γ_1	γ_2	Γ_2	γ_3	Γ_3	γ_4	Γ_4
1889.	°	°	°	°	°	°	°	°
Feb. 26	0·0106	271·0	0·4923	267·38	0·1342	245·93	0·3130	331·47
Apr. 27	·0105	268·7	·4923	265·45	·1336	245·51	·3122	331·44
June 26	·0103	266·3	·4923	263·52	·1331	245·10	·3114	331·39
Aug. 25	·0102	264·0	·4923	261·59	·1327	244·70	·3107	331·32
Oct. 24	0·0101	261·8	0·4924	259·66	0·1323	244·31	0·3100	331·23

The following is a list of Greenwich mean times, when the zero meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc:

1889.	I. (877°·90) h m	II. (870°·27) h m	1889.	I. (877°·90) h m	II. (870°·27) h m
Feb. 26	13 6·4	13 17·9	Apr. 1	13 59·6	11 25·2
27	18 38·1	19 5·0	2	19 31·1	17 12·2
28	14 19·1	14 56·5	3	15 12·1	13 3·5
Mar. 1	19 50·8	20 43·7	4	10 53·1	18 50·5
2	15 31·9	16 35·1	5	16 24·5	14 41·8
3	11 12·9	12 26·5	6	12 5·5	10 33·2
4	16 44·6	18 13·7	7	17 37·0	16 20·2
5	12 25·6	14 5·1	8	13 17·9	12 11·5
6	17 57·3	19 52·3	9	18 49·4	17 58·5
7	13 38·3	15 43·6	10	14 30·3	13 49·8
8	19 9·9	11 35·1	11	10 11·3	9 41·1
9	14 51·0	17 22·3	12	15 42·7	15 28·0
10	10 32·1	13 13·7	13	11 23·7	11 19·3
11	16 3·6	19 0·8	14	16 55·1	17 6·3
12	11 44·7	14 52·2	15	12 36·0	12 57·6
13	17 16·3	10 43·6	16	8 17·0	8 48·9
14	12 57·3	16 30·7		18 7·4	18 44·5
15	18 28·9	12 22·1	17	13 48·4	14 35·8
16	14 9·9	18 9·2	18	9 29·3	10 27·1
17	19 41·5	14 0·6		19 19·8	20 22·7
18	15 22·5	19 47·7	19	15 0·7	16 14·0
19	11 3·5	15 39·1	20	10 41·6	12 5·3
20	16 35·1	11 30·4	21	16 13·0	17 52·2
21	12 16·1	17 17·5	22	11 53·9	13 43·4
22	17 47·6	13 8·9	23	17 25·3	9 34·7
23	13 28·6	18 55·9	24	13 6·2	15 21·6
24	19 0·1	14 47·3	25	8 47·1	11 12·9
25	14 41·2	10 38·7	26	14 18·5	16 59·8
26	10 22·2	16 25·7	27	9 59·4	12 51·0
27	15 53·7	12 17·1	28	15 30·7	8 42·3
28	11 34·7	18 4·1	29	11 11·6	14 29·2
29	17 6·2	13 55·5	30	16 42·9	10 20·4
30	12 47·2	19 42·5	May 1	12 23·8	16 7·3
31	18 18·7	15 33·8	2	8 4·7	11 58·5

1889.	I. (877°·90) h m	II. (870°·27) h m
May 3	13 36·1	17 45·4
4	9 16·9	13 36·6
5	14 48·3	9 27·9
6	10 29·1	15 14·7
7	16 0·4	11 5·9
8	11 41·3	16 52·8
9	17 12·6	12 44·0
10	12 53·5	8 35·2
11	8 34·3	14 22·0
12	14 5·6	10 13·2
13	9 46·5	16 0·1
14	15 17·8	11 51·3
15	10 58·6	17 38·1
16	16 29·9	13 29·3
17	12 10·7	9 20·5
18	17 42·0	15 7·3
19	13 22·9	10 58·5
20	9 3·7	16 45·3
21	14 35·0	12 36·5
22	10 15·8	8 27·6
23	15 47·1	14 14·4
24	11 27·9	10 5·6
25	16 59·1	15 52·4
26	12 40·0	11 43·6
27	8 20·8	7 34·7
	18 11·2	17 30·3
28	13 52·0	13 21·5
29	9 32·9	9 12·7
	19 23·3	19 8·3
30	15 4·1	14 59·5
31	10 44·9	10 50·6
June 1	6 25·7	6 41·8
	16 16·2	16 37·4
2	11 57·0	12 28·6

1889.	I. (877°·90) h m	II. (870°·27) h m
June 3	7 37·8	8 19·7
	17 28·2	18 15·3
4	13 9·0	14 6·5
5	8 49·8	9 57·7
6	14 21·1	15 44·4
7	10 1·9	11 35·6
8	15 33·1	17 22·3
9	11 13·9	13 13·5
10	16 45·2	9 4·7
11	12 26·0	14 51·4
12	8 6·8	10 42·6
13	13 38·0	16 29·3
14	9 18·8	12 20·5
15	14 50·0	8 11·7
16	10 30·9	13 58·4
17	16 2·1	9 49·6
18	11 42·9	15 36·4
19	7 23·7	11 27·5
20	12 55·0	7 18·7
21	8 35·8	13 5·5
22	14 7·0	8 56·6
23	9 47·8	14 43·4
24	Transit of Earth and Moon across Sun's disc. *Vide M. Not.* vol. xlvi. p. 163.	
	15 19·1	10 34·6
25	10 59·9	16 21·3
26	16 31·2	12 12·5
27	12 12·0	8 3·7
28	7 52·8	13 50·5
29	9 22 Middle of second tabular eclipse of *Sat. IV.**	
	13 24·1	9 41·6
30	9 4·9	15 28·4

* There will be probably no real eclipse, but the satellite will remain visible as a speck of light skirting the margin of the total shadow. *Vide Monthly Notices*, vol. xliv. p. 243.

1889.	I. (877°·90) h m	II. (870°·27) h m
July 1	14 36·2	11 19·6
2	10 17·0	7 10·8
3	15 48·3	12 57·6
4	11 29·2	8 48·9
5	7 10·0	14 35·7
6	12 41·3	10 26·9
7	8 22·2	6 18·1
	18 12·6	16 13·7
8	13 53·5	12 4·9
9	9 34·4	7 56·2
10	15 5·7	13 43·0
11	10 46·5	9 34·2
12	6 27·4	5 25·5
	16 17·9	15 21·1
13	11 58·8	11 12·3
14	7 39·7	7 3·6
	17 30·1	16 59·2
15	13 11·0	12 50·4
16	3 25 Middle of first real eclipse of *Sat. IV.* Duration uncertain.	
	8 51·9	8 41·7
17	14 23·3	14 28·6
18	10 4·2	10 19·9
19	5 45·1	6 11·1
	15 35·6	16 6·8
20	11 16·5	11 58·0
21	6 57·4	7 49·3
	16 47·9	17 45·0
22	12 28·8	13 36·3
23	8 9·8	9 27·5
24	13 41·2	15 14·5
25	9 22·1	11 5·8
26	5 3·1	6 57·1
	14 53·5	16 52·8
27	10 34·5	12 44·1
28	15·5	8 35·4

1889.	I. (877°·90) h m	II. (870°·27) h m
July 29	11 46·9	14 22·4
30	7 27·9	10 13·7
31	12 58·4	6 5·0
Aug. 1	8 40·3	11 52·0
	18 30·8	21 47·7
	21 29 Middle of second eclipse of *Sat. IV.*	
2	14 11·8	7 43·4
3	9 52·8	13 30·4
4	5 33·8	9 21·7
	15 24·3	19 17·4
5	11 5·3	15 8·8
6	6 46·3	11 0·1
7	12 17·8	6 51·5
8	7 58·9	12 38·6
9	13 30·4	8 29·9
10	9 11·4	4 21·3
	19 1·9	14 17·0
11	4 52·5	10 8·4
	14 43·0	20 4·1
12	10 24·0	5 59·8
	20 14·5	15 55·5
13	6 5·1	11 46·9
14	11 36·6	7 38·3
15	7 17·7	13 25·4
16	12 49·3	9 16·8
17	8 30·4	15 4·0
18	14 2·0	10 55·4
	15 34 Middle of third eclipse of *Sat. IV.*	
19	9 43·0	6 46·8
20	5 24·1	12 34·0
21	10 55·8	8 25·4
22	6 36·8	14 12·6
23	12 8·5	10 4·0
24	7 49·6	5 55·5
25	13 21·2	11 42·7

1889.	I. (877°·90) h m	II. (870°·27) h m
Aug. 26	9 2·3	7 34·1
27	14 34·0	13 21·3
28	10 15·1	9 12·8
29	5 56·2	5 4·3
	15 46·8	15 0·0
30	11 27·9	10 51·5
31	7 9·1	6 43·0
Sept. 1	12 40·8	12 30·2
2	8 21·9	8 21·7
3	4 3·1	4 13·2
	13 53·6	14 9·0
4	9 39 Middle of fourth eclipse of *Sat. IV.*	
4	9 34·8	10 0·5
5	5 15·9	5 52·0
	15 6·5	15 47·7
6	10 47·7	11 39·3
7	6 28·8	7 30·8
8	12 0·6	13 18·1
9	7 41·7	9 9·6
10	3 22·9	5 1·1
	13 13·5	14 56·9
11	8 54·7	10 48·4
12	4 35·9	6 40·0
13	10 7·6	12 27·3
14	5 48·8	8 18·8
15	11 20·6	14 6·1
16	7 1·8	9 57·7
17	12 33·6	5 49·3
18	8 14·8	11 36·6
19	3 56·0	7 28·2
20	9 27·9	13 15·5
21	5 9·1	9 7·1
22	10 40·9	4 58·7
23	6 22·1	10 46·0

1889.	I. (877°·90) h m	II. (870°·27) h m
Sept. 24	11 54·0	6 37·6
25	7 35·2	12 25·0
26	3 16·4	8 16·6
27	8 48·3	4 8·2
28	4 29·5	9 55·6
29	10 1·4	5 47·2
30	5 42·6	11 34·6
Oct. 1	11 14·5	7 26·2
2	6 55·7	13 13·6
3	12 27·6	9 5·2
4	8 8·9	4 56·8
5	3 50·1	10 44·2
6	9 22·0	6 35·9
7	5 3·3	12 23·3
8	10 35·2	8 14·9
9	6 16·4	4 6·5
10	11 48·3	9 54·0
11	7 29·6	5 45·6
12	3 10·9	11 33·1
13	8 42·8	7 24·7
14	4 24·1	3 16·3
	14 14·8	13 12·2
15	9 56·0	9 3·7
16	5 37·3	4 55·4
17	11 9·2	10 42·8
18	6 50·5	6 34·6
19	12 22·5	12 22·0
20	8 3·8	8 13·7
21	3 45·0	4 5·4
	13 35·7	14 1·2
22	9 17·0	9 52·8
23	4 58·3	5 44·5
24	10 30·2	11 32·0
25	6 11·5	7 23·6

In order to reduce the longitudes of system I of the three preceding ephemerides to those adopted in the present ephemeris, the following corrections, duly interpolated, must be applied:

1885, Nov. 14	+58°·0	1887, Jan. 8	+159°·2	1888, Jan. 3	+33°·2
1886, Jan. 13	+28·0	Mar. 9	138·2	Mar. 3	+12·2
Mar. 14	− 2·0	May 8	117·2	May 2	− 8·8
May 13	−32·0	July 7	96·2	July 1	−29·8
July 12	−62·0	Sept. 5	+75·2	Aug. 30	−50·8

The passages over the middle of the illuminated disc observed by Mr. A. S. Williams, and one, observed 1887, July 16, by Mr. Denning, give the following longitudes of the two equatorial spots according to system I of the present ephemeris:

G.M.T.		Long.	Long.	G.M.T.	Long.	Long.
1887.	h m	°	°	1888. h m	°	°
Mar. 16	13 34 W.	...	177·6	May 13 14 18 W.	...	167·6
18	14 45 "	...	176·9	15 11 9	8·4	
23	13 0 "	...	183·0	19 13 30·5	6·8	
July 16	8 12 D.	...	169·2	20 13 50	...	176·7
1888. Mar. 1	14 57 W.	...	177·7	21 14 44	7·7	
25	14 50	4·2		22 10 22	5·9	
Apr. 1	14 9	5·1		23 10 32	...	170·1
3	15 21	5·0		24 11 30	3·5	
4	15 31	...	169·1	25 11 37	...	165·8
6	12 13	4·4		June 1 11 18	...	180·3
8	13 20	1·2		2 12 7	8·2	
14	11 40	...	168·3	3 12 44	...	188·7
20	15 26	...	174·2	10 11 59·5	...	187·5
26	14 19	1·6		14 9 27	6·4	
29	15 55±	...	174·2±	16 10 29	0·1	
May 1	12 26	2·8		17 11 8	...	181·9
3	13 44·5	6·8		22 9 15	...	182·7
5	14 55	5·8		30 9 10	3·0	
10	13 1·5	6·8		July 1 9 49·5	...	185·0
11	13 9	...	169·4	18 10 12	2·5	
12	14 13	6·5		19 10 46	...	181·1
13	9 52	5·4		Aug. 25 8 19·5	...	169·6

Note on the Values of the Constants for the new Dearborn Observatory.
By Lieutenant-General Tennant.

Since the proofs were passed I have received a communication as to the place of this Observatory from Professor Hough, the director, giving the following results:

Longitude from Greenwich. Time.	Parts of day.	Corr. to S.T.M.N.	Lat.	tan ϕ'.	log A.	log D.	log P.
h m s	d	s	° ′				
−5 50 42	−0·243542	+57·61	+42 03	9·9522	9·6388	0·7671	0·9428

Errata in Professor Holden's Observations of Nebulæ, Monthly Notices, Vol. XLVIII. No. 9.

Figure at bottom of p. 386—Insert B in the middle of the triangle which has *d*, *c* and 14 for vertices.

Page 390, line 4 from top, *dele* "blue."

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. JANUARY 11, 1889. No. 3

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Henry Lord Boulton, Carácas, Venezuela, South America;
Ernest William Brown, B.A., Christ's College, Cambridge, and 16 Milton Terrace, Aulaby Road, Hull;
Samuel Fellows, Tynwald Villas, Lower Villier Street, Wolverhampton;
John James Lewis Goodridge, Bevis Mount, Southampton;
Jesse Scoffin Nimkey, Blanchard House, Whitehall Road, Woodford Wells, Essex;
Frederick William Nash, Holmesdale, Birchfield Road, Birmingham; and
William Schooling, Brechin House, Rivercourt, Hammersmith, W.;

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposer from personal knowledge being appended:—

The Rev. Charles Douglas Percy Davies, M.A., late Scholar of Pembroke College, Oxford, Ringmer, Lewes (proposed by Professor C. Pritchard); and
Edouard Jules Laumonier, Submarine Telegraph Engineer, Fairfield, Underhill Road, Dulwich (proposed by B. G. Jenkins).

Observations of the Moon, made at the Radcliffe Observatory, Oxford, during the year 1888, *and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.* By E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

The present paper contains the right ascensions and north polar distances of the Moon, as deduced from the observations made at the Radcliffe Observatory during the year 1888. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions:—

(1) That the mean times, found in the usual way from the sidereal times at mean noon, given in the *Nautical Almanac*, were *not* changed in 1864 by the adoption of a different unit of time.

(2) That these mean times *were* changed by the adoption of a different measure of time in 1864 to fix the positions of the clock stars relatively to the Sun, in accordance with the views which I have explained in papers communicated to the Society.

It will be seen that the mean annual error of Hansen's Tables from 1847 to 1863 is $-1''\cdot30$, and that no law of regular increase is apparent; but that, with the argument in the Tables taken out in the usual way, the mean annual error has since increased at an average rate of $0''\cdot73$ per annum, the error now amounting to about $+17''$. The mean annual error of Hansen's Tables from 1864 to 1888 taken out with the *corrected* argument is $-1''\cdot28$, which is almost identically the same as the mean error between 1847 and 1863.

For facilities for an accurate comparison between Hansen's Lunar Tables and observations we are again indebted to the places published in the *Connaissance des Temps*.

TABLE I.

Radcliffe Observations of the Moon, 1888.

Day, 1888.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	Seconds of Hansen's R.A.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.	Observed N.P.D.	Seconds of Hansen's N.P.D.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Jan. 23	35·73	W.	4 4 24·84	25·71	+0·87	−1·22	−0·35	74 10 47·65	43·82	−3·83	+4·11	+0·28
26	35·74	W.	6 48 16·55	17·53	+0·98	−1·39	−0·41	69 32 20·94	19·90	−1·04	−0·04	−1·08
27	35·75	R.	7 46 56·48	57·56	+1·08	−1·41	−0·33	70 11 1·40	3·02	+1·62	−1·82	−0·20
Feb. 1	35·77	F. B.	12 35 18·51	19·73	+1·22	−1·33	−0·11	88 55 49·42	51·87	+2·45	−7·44	−4·99
25	35·86	F. B.	9 16 22·84	24·13	+1·29	−1·42	−0·13	73 29 3·61	7·46	+3·85	−4·47	−0·62
Mar. 21	35·96	F. B.	6 52 24·05	24·98	+0·93	−1·35	−0·42	69 20 57·12	56·55	−0·57	−0·19	−0·76
April 2	36·01	R.	18 44 41·76	43·27	+1·51	−1·45	+0·06	110 45 14·50	14·28	−0·22	−0·04	−0·26
26	36·11	W.	15 8 42·41	43·93	+1·52	−1·50	+0·02	102 35 43·30	48·49	+5·19	−6·68	−1·49
30	36·12	R.	19 22 9·40	10·98	+1·58	−1·47	+0·11	110 46 27·72	26·63	−1·09	+1·14	+0·05
May 18	36·19	R.	9 54 29·76	30·34	+0·58	−1·33	−0·75	75 9 13·40	15·29	+1·89	−5·25	−3·36
21	36·21	F. B.	12 40 2·47	3·40	+0·93	−1·36	−0·43	89 15 19·02	23·48	+4·46	−7·91	−3·45
23	36·21	F. B.	14 36 24·76	25·94	+1·18	−1·47	−0·29	100 0 58·25	64·43	+6·18	−7·34	−1·16
25	36·22	R.	16 42 21·76	23·00	+1·24	−1·57	−0·33	108 17 46·27	49·71	+3·44	−4·29	−0·85
June 18	36·32	W.	13 13 59·98	60·80	+0·82	−1·35	−0·53	92 21 41·73	45·68	+3·95	−7·78	−3·83
19	36·32	R.	14 10 14·58	15·27	+0·69	−1·39	−0·70	97 37 23·86	28·23	+4·37	−7·49	−3·12

Day, 1888.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	Seconds of Hansen's R.A.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.	Observed N.P.D.	Seconds of Hansen's N.P.D.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
June 25	36 35	W.	20 27 4·56	6·20	+1·64	−1·48	+0·16	109 31 4·40	2·25	−2·15	+3·14	+0·99
July 20	36·45	R.	17 50 16·57	17·65	+1·08	−1·55	−0·47	110 34 15·22	16·22	+1·00	−2·06	−1·06
23	36·46	W.	20 58 8 47	10·09	+1 62	−1·44	+0·18	108 15 52·84	49·30	−3·54	+4·00	+0·46
26	36·47	R.	23 39 44·55	45·72	+1·17	−1·21	−0·04	96 44 42·23	35·31	−6·92	+6·64	−0·28
Aug. 18	35·56	F. B.	19 32 12·19	13·54	+1·35	−1·50	−0·15	110 56 17·92	15·30	−2 62	+1·40	−1·22
22	36·58	W.	23 17 35·47	36 80	+1·33	−1·25	+0·08	98 40 38·67	32 64	−6·03	+6·54	+0·51
23	36·58	F. B.	0 7 6·04	7·47	+1·43	−1·20	+0·23	94 7 48·19	42·59	−5·60	+6·84	+1·24
Sept. 12	36 66	W.	17 9 15 87	17·28	+1·41	−1·50	−0·09	103 32 49·47	52·99	+3·52	−3·32	+0·20
13	36 67	R.	18 10 59·82	61·03	+1·21	−1·51	−0·30	111 7 28 98	31·07	+2·09	−1·28	+0 81
17	36·68	W.	22 5 23·75	25·01	+1·26	−1·32	−0·06	104 24 9·69	6·15	−3·54	+5·49	+1·95
19	36·69	W.	23 47 30·73	31·97	+1·24	−1·21	+0·03	95 55 47 98	41·58	−6·40	+6·79	+0·39
20	36·69	R.	0 35 40·96	42·03	+1·07	−1·18	−0·11	91 17 25 74	19·02	−6·72	+6·92	+0·20
Oct. 11	36·78	R.	18 53 52·68	54·03	+1·35	−1·53	−0·18	111 37 59·57	58·13	−1·44	+0·15	−1·29
15	36·79	R.	22 41 10 66	11·91	+1·25	−1·26	−0·01	101 51 49·32	43·71	−5·61	+6·11	+0·50
17	36·80	R.	0 19 3·11	4·21	+1·10	−1·17	−0·07	92 56 59·91	53·89	−6·02	+6·93	+0·91
20	36·81	F. B.	2 39 27·46	28·65	+1·19	−1·17	+0 02	79 31 13·66	10 15	−3·51	+6·01	+2·50

Day, 1888.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	Seconds of Hansen's R.A.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.	Observed N.P.D.	Seconds of Hansen's N.P.D.	Hansen *minus* Observed. **Uncorrected** for Error in Time.	Correction due to Error in Time.	Hansen *minus* Observed. **Corrected** for Error in Time.
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Oct. 22	36·82	R.	4 16 12·52	13·62	+1·10	−1·23	−0·13	72 34 58·28	55·64	−2·64	+4·16	+1·52
23	36·83	F. B.	5 6 41·72	42·92	+1·20	−1·27	−0·07	70 11 21·64	21·15	−0·49	+2·92	+2·43
Nov. 13	36·91	F. B.	0 4 30·61	31·85	+1·24	−1·18	+0·06	94 32 61·26	55·75	−5·51	+6·92	+1·41
16	36·92	F. B.	2 23 49·37	50·51	+1·14	−1·16	−0·02	80 54 38·65	33·76	−4·89	+6·29	+1·40
17	36·93	R.	3 11 0·90	1·87	+0·97	−1·19	−0·22	76 55 30·80	25·21	−5·59	+5·57	−0·02
20	36·94	F. B.	5 41 11·13	12·37	+1·24	−1·30	−0·06	68 55 28·07	24·66	−3·41	+2·05	−1·36
25	36·96	R.	10 7 55·77	56·87	+1·10	−1·31	−0·21	75 12 20·37	23·11	+2·74	−5·61	−2·87
27	36·97	R.	11 53 32·93	33·98	+1·05	−1·32	−0·27	84 14 52·81	59·08	+6·27	−7·67	−1·40
Dec. 7	37·01	R.	21 8 54·40	55·66	+1·26	−1·47	−0·21	103 29 54·49	50·07	−4·42	+4·51	+0·09
11	37·02	F. B.	0 36 21·22	22·43	+1·21	−1·17	+0·04	91 34 52·32	47·89	−4·43	+7·07	+2·64
12	37·03	R.	1 22 42·37	43·21	+0·84	−1·15	−0·31	86 54 23·45	18·24	−5·21	+6·90	+1·69
13	37·03	F. B.	2 8 46·53	47·89	+1·36	−1·15	+0·21	82 25 12·29	7·93	−4·36	+6·50	+2·14
26	37·08	W.	13 19 22·37	23·70	+1·33	−1·33	0·00	92 41 23·28	30·97	+7·69	−8·03	−0·34
Mean of Errors, without regard to sign			...	...	s 1·185	...	s 0·204	... ...	...	″ 8·830	...	″ 1·348
Mean Errors for Year ...	...	...	...	...	+1·185	...	−0·149					

Observers; W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

Table II.

Radcliffe Observations of the Moon, 1888.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance. **Uncorrected** *and* **Corrected** *for the change in Tabular Mean Time introduced in the year* 1864.

Day, 1888.		Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.	Errors of E.N.P.D. (Hansen *minus* Observed) Uncorrected.	Corrected.
		″	″	″	″
Jan.	23	+13·11	− 5·03	−1·33	−0·70
	26	+13·64	− 5·83	−2·17	−0·60
	27	+15·32	− 4·63	−1·12	+0·63
Feb.	1	+17·89	− 3·50	−4·95	−3·95
Feb.	25	+18·86	− 1·97	−1·90	−0·03
March	21	+12·98	− 5·95	−1·74	−0·23
April	2	+21·14	+ 0·86	+1·40	−0·19
April	26	+22·93	− 0·12	−1·08	−1·52
	30	+22·15	+ 1·52	+2·03	+0·27
May	18	+ 8·56	−11·38	−1·08	+0·54
	21	+14·67	− 7·33	−1·37	−0·64
	23	+18·57	− 4·45	+0·46	+0·23
	25	+17·99	− 4·78	+1·06	−0·22
June	18	+12·92	− 8·84	−1·00	−0·53
	19	+11·19	−10·91	+0·65	+0·57
	25	+23·03	+ 1·96	+3·47	+1·50
July	20	+15·20	− 6·63	+0·73	−0·94
	23	+23·14	+ 2·33	+3·03	+1·16
	26	+18·80	− 0·44	+0·57	−0·49
Aug.	18	+19·11	− 1·88	+0·35	−1·53
	22	+20·54	+ 0·89	+2·19	+0·93
	23	+21·98	+ 2·68	+3·40	+2·52

Day, 1888.		Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Uncorrected	Corrected.
		″	″	″	″
Sept.	12	+20·22	− 1·25	+1·80	+0·31
	13	+16·90	− 4·21	+2·39	+0·73
	17	+18·41	− 1·50	+3·10	+1·52
	19	+19·60	+ 0·25	+1·50	+0·54
	20	+17·50	− 1·60	+0·13	−0·47
Oct.	11	+18·90	− 2·38	+0·32	−1·52
	15	+19·14	− 0·32	+1·69	+0·41
	17	+17·64	− 1·33	+1·01	+0·42
	20	+17·85	− 0·49	+2·03	+2·47
	22	+15·99	− 2·10	+0·15	+1·17
	23	+16·93	− 1·22	+1·07	+2·33
Nov.	13	+19·29	+ 0·26	+2·34	+1·65
	16	+17·64	− 0·74	+0·83	+0·23
	17	+15·21	− 3·10	−1·58	−0·88
	20	+17·48	− 0·80	−2·86	−1·39
	25	+15·92	− 3·87	−3·04	−1·61
	27	+16·94	− 4·27	−0·50	+0·32
Dec.	7	+18·44	− 2·88	+1·00	−0·79
	11	+18·55	− 0·49	+3·07	+2·67
	12	+13·67	− 4·96	−0·11	−0·17
	13	+20·59	+ 2·22	+2·75	+3·07
	26	+21·46	− 0·13	−0·35	−0·31
Mean of Errors, without regard to sign		**...17″·682**	**3″·052**	**1″·607**	**1″·020**
Mean Errors for Year		**+17″·682**	**−2″·462**		

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 to 1888, as computed from Hansen's Tables.

Uncorrected *and* **Corrected** *on and after 1864 for the change in Tabular Mean Time introduced in the year 1864.*

Year.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.
	″	″
1847	+ 1·07	+ 1·07
1848	+ 0·20	+ 0·20
1849	− 0·47	− 0·47
1850	− 0·28	− 0·28
1851	− 1·29	− 1·29
1852	− 0·92	− 0·92
1853	− 1·63	− 1·63
1854	− 1·68	− 1·68
1855	− 0·87	− 0·87
1856	− 0·96	− 0·96
1857	− 1·86	− 1·86
1858	− 1·98	− 1·98
1859	− 1·80	− 1·80
1860	− 2·90	− 2·90
1861	− 2·19	− 2·19
1862	− 2·83	− 2·83
1863	− 1·61	− 1·61
1864	+ 0·12	− 0·81
1865	+ 1·27	− 0·22
1866	+ 2·14	− 0·22
1867	+ 3·48	+ 0·36
1868	+ 4·12	+ 0·28
1869	+ 4·28	− 0·35
1870	+ 4·83	− 0·66
1871	+ 6·96	+ 0·44
1872	+ 7·31	+ 0·10
1873	+ 8·24	+ 0·20
1874	+ 9·29	+ 0·56
1875	+ 9·87	+ 0·36
1876	+ 9·80	− 0·50
1877	+ 9·23	− 1·90
1878	+ 8·22	− 3·60
1879*	+ 9·63	− 3·12
1880	+ 10·89	− 2·77
1881	+ 10·51	− 4·06
1882†	+ 12·68	− 2·51
1883	+ 14·71	− 1·50
1884	+ 14·65	− 1·91
1885	+ 15·20	− 1·82
1886	+ 15·34	− 2·53
1887	+ 15·70	− 3·25
1888‡	+ 17·68	− 2·46

* All to 1879, Greenwich observations.
† 1880 to 1882, Mean of Greenwich and Radcliffe.
‡ 1883 and since, Radcliffe only.

Radcliffe Observatory, Oxford:
1889, *January* 0.

On the Determination of Errors of Graduation without Cumulative Error, and the Application of the Method to the Scales of the Cape Heliometer. By David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.

The methods available for determining the accidental errors of graduation of a scale or circle may be divided into two classes—

1. The methods in which the error of successive subdivision is cumulative.

2. Those methods in which this error is non-cumulative.

The first of these, which at best is weak and unsatisfactory, has hitherto been almost exclusively employed; whilst the second method has been rarely, and then only partially, used.

The only instance which occurs to me of the employment of the second method in ordinary astronomical practice is in the first stage of the investigation of the division errors of a Transit Circle. The operation may serve for illustration. Let us suppose that, as in the Greenwich and Cape instruments, the graduated circle is read by six microscopes, which we shall call A, B, C, D, E, F, and that the true angular distances between the zeros of these microscopes are respectively $60°+d_b$, $60°+d_c$, $60°+d_d$, $60°+d_e$, $60°+d_f$, $60°+d_a$ (when $60°+d_b$ represents the angle between microscopes A and B, and so on), and that the true lengths of the six fundamental arcs of the circle are $60°+e_{60}$, $60°+e_{120}$, $60°+e_{180}$, $60°+e_{240}$, $60°+e_{300}$, $60°+e_{360}$, then the errors E of divisions will be—

$$\left.\begin{aligned}E_{60} &= e_{60} \\ E_{120} &= e_{60}+e_{120} \\ E_{180} &= e_{60}+e_{120}+e_{180} \\ E_{240} &= e_{60}+e_{120}+e_{180}+e_{240} \\ E_{300} &= e_{60}+e_{120}+e_{180}+e_{240}+e_{300} \\ E_{360} &= e_{60}+e_{120}+e_{180}+e_{240}+e_{300}+e_{360}\end{aligned}\right\} \quad \ldots\ldots \quad (1)$$

It is evident also that we have

$$d_a+d_b+d_c+d_d+d_e+d_f=0$$

and

$$e_{60}+e_{120}+e_{180}+e_{240}+e_{300}+e_{360}=0 \quad \ldots\ldots \quad (2)$$

Therefore if we compare the arc $(60°+e_{60})$ successively with each of the six microscope intervals, we obtain

e_{60} = mean excess of this arc over mean of micrometer intervals,

with the probable error

$$\pm\frac{\epsilon}{\sqrt{6}}$$

where ϵ is the probable error of one comparison.

Similarly, we may determine each of the quantities e_{120}, e_{180}, . . . e_{360}, with similar probable errors.

But when we come to the computation of the division errors E_{60}, E_{120}, &c., by our formula (1) we shall probably find that our equation (2) is not satisfied; indeed the probability is that the sum of the corrections will differ from o by $\pm\epsilon$.

This, therefore, represents the method in which the process of subdivision creates cumulative error.

But if instead of observing only the space o° to 60°, we read all the microscopes whilst division o is brought successively under all the microscopes, we automatically satisfy our equation (2) as well as our equation (1), and the process is not affected by cumulative error (since any error of reading which would increase the apparent length of one space would diminish the apparent length of the adjoining space), so long as it can be assumed that the intervals between the microscopes remain unchanged. This condition can be practically realised by repeating the order of observation in the opposite sense.

The general condition which alone secures freedom from cumulative error is

> For a circle.—*There shall be as many microscopes (or the equivalent for as many microscopes) as the number of spaces into which the circle is to be subdivided.*

If it is required to subdivide a straight line or the portion of a circle into n spaces (i.e. when the beginning and ending of scale are not identical), the number of the microscopes (or their equivalent) must be $n+1$.

Thus, if it were required to determine the division errors of a circle to each single degree without cumulative error, it would obviously be impossible to provide 360 microscopes for the purpose, but it is comparatively easy to provide an equivalent arrangement. In the Transit Circle made by T. Cooke & Sons, of York, for Mr. Newall under the superintendence and direction of Mr. Marth, two concentric circles are provided, one of which is firmly bolted to the axis, whilst the second circle may be rotated with respect to the first. The graduated surfaces of both circles are in the same plane, and nearly contiguous, so that the graduations of both circles may be read off by the same microscope. The operation of determining the division error of each degree of both circles may then be carried out without cumulative error, as follows.

The movable circle is turned relative to the fixed circle till the divisions marked o° on both circles are coincident; the movable circle is then clamped. Each degree of the circle is then brought successively under the microscope, and the divisions of both circles are read. When this has been done the movable circle is unclamped and turned till its graduation marked o coincides with the division marked 1° on the fixed circle,

and all the corresponding divisions on both circles are again read. The same operation is then repeated after shifting the movable circle so that its division marked o coincides with that marked 2° on the fixed circle, and so on until each degree-space of the fixed circle has been compared with each degree-space of the movable circle. The mean excess of any degree-space of the fixed circle over the mean of the 360 degree-spaces of the movable circle is then, obviously, the excess of the length of that nominal degree over a true degree.

In this way the true length of each nominal degree-space of the fixed circle is directly obtained, with a mean error

$$= \pm \frac{\epsilon}{\sqrt{360}},$$

where E is the mean error of a single comparison of a degree-space on the two circles. Further, the nature of the process automatically fulfils the condition that the sum of the degree-spaces so obtained is = o, and that there is no cumulative error in the formation of the division errors by successive summations of the errors of the single degree-spaces, so that all the division errors are determined with the same accuracy—viz. with a mean error

$$= \pm \frac{\epsilon}{\sqrt{360}}.$$

The method is perfected if instead of one microscope two microscopes 180° apart are employed, so that the errors of *diameters* are determined with complete elimination of possible changes of eccentricity of the movable circle. The method may be obviously extended to the determination of each single subdivision of the degree-spaces. So far as I am aware, however, the instrument designed by Mr. Marth, although it was made, has never been used for astronomical purposes, and we have no records of the results of the investigation of division errors by the method in question.

But I was so much impressed by the strength of Mr. Marth's proposed method and by the inefficiency of previously existing methods for investigating the errors of graduation of heliometer scales, that I determined, if possible, in the new Cape heliometer to provide means for determining the division errors of the scales by some method which would permit the absolute error of each division to be known with the utmost accuracy with which the scales can be read.

In vol. ii. of the Dun Echt publications, p. 48, it is shown that although the principal divisions of the Dun Echt heliometer could be determined with a probable error less than $\pm 0''\cdot02$, the probable error of the determination of the errors of graduation amounted in some parts of the scale to $\pm 0''\cdot1$ (a quantity greater than the probable error of a single complete observation), and

which no amount of observation would sensibly diminish, because at p. 50 of the same work it is further shown:

1. There is a limited accuracy in the determination of the error of each division, beyond which no amount of observation will strengthen the result.
2. This limit of accuracy is different for different divisions, and seems to depend on the perfection of the surface and the cleanness of the cut.
3. For any division the limit of accuracy is from one-third to one-fourth of the probable error of a single careful bisection.

It is therefore useless to trust to the mean of a very large number of observations to reduce the accumulation of errors which must arise in the process of successive subdivision, and it is of course hopeless to attempt to reach results of the highest accuracy by any process except one in which the errors are non-cumulative.

In order to secure divisions with very clean-cut edges, I proposed to Messrs. Repsold that they should, if possible, avoid the usual process of "charcoaling" the scales after division. This process consists in rubbing the divisions with a stick of fine charcoal to remove the "burr" at the edge of the divisions; but it does so at the expense of widening the cut of the division, and destroys the absolute cleanness of the narrow, deep furrow which is cut out by a well-selected diamond, the cutting front and edge of which have been produced by cleavage. At first I thought that it might be better to leave the "burr" rather than destroy the perfection of the division by the charcoaling process, but Messrs. Repsold pointed out that if the "burr" were not removed it would not be possible to clean the scales by the usual plan of wiping with silk or soft linen, and the "burrs" would catch in the texture of the cleaning-material, and possibly be liable when so rubbed to change the appearance of the division under the microscope. I then suggested the possibility of polishing down the entire surface of the scale with a small flat metal polisher charged with some grinding- or polishing-material. If the divisions are cut sufficiently deep, this plan would enable the artist gradually to remove not only the entire surface affected by the "burr," but to regulate the equality of the width of the divisions along the entire scale. Messrs. Repsold undertook the construction of the scales on this plan, and one member of the firm devoted three months to experimental work and to the completion of the exquisite scales which are fitted to the Cape heliometer. These scales are made of an alloy of iridium and platinum, with polished surfaces, and the divisions are so fine as to be almost invisible to the naked eye. Each scale is one decimetre in length, divided into 200 parts of 0·5 millimetre each. Four revolutions of the micrometer correspond with one division,

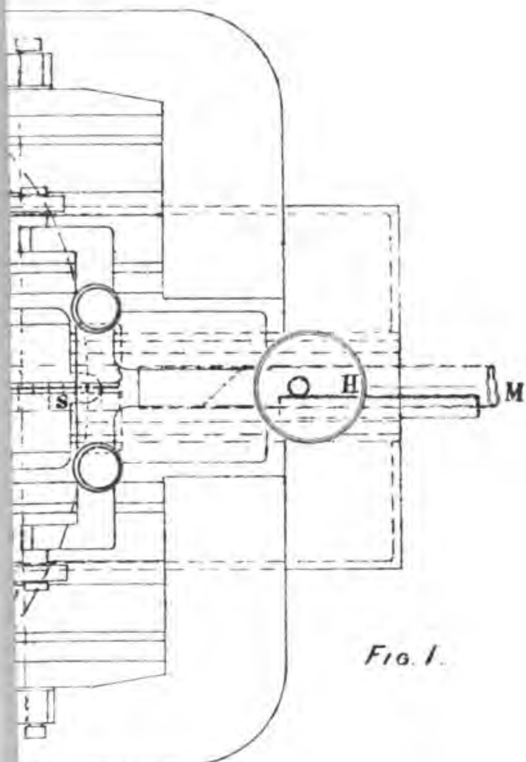


Fig. 1.

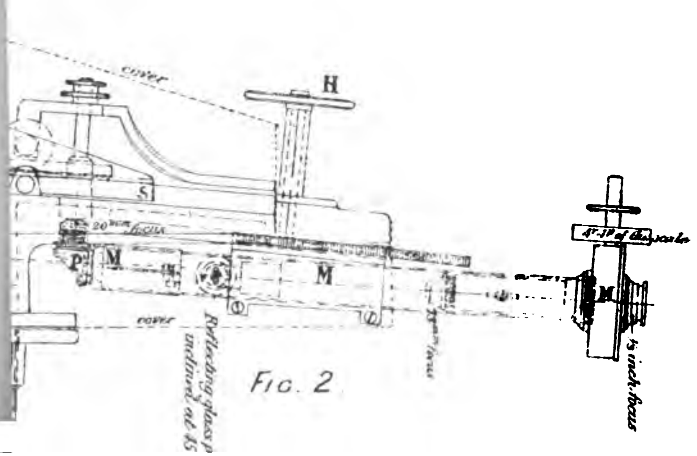


Fig. 2.

and one revolution is equivalent to 10″ of arc.* The microscope magnifies 100 diameters, and yet, under this unusual power, the divisions, when illuminated by light reflected from a dead white surface, present sharp clean edges, such as I have never before seen in like perfection on any other scales or divided circles which I have had the opportunity of using.

When the image of a division is placed symmetrically between the parallel spider-webs of the micrometer a clean sharp white line appears between the inner edge of either web and the division, and the eye can judge so sharply of the equality of the thickness of these white lines that it is seldom that two consecutive pointings on the division differ by more than $\frac{1}{10}$th part of a division of the micrometer head, i.e. by 0″·01, which is entirely satisfactory.

In order to permit the comparison of any part of one scale with any part of the other, I suggested to Messrs. Repsold that the reading microscope should be so arranged as to be capable of being directed to any part of the scales. It soon became evident on discussion that, to fulfil this condition, it would be necessary to increase very materially and inconveniently the diameter of the central cylinder which rotates in the cradle, and of the tube generally, and consequently to diminish the ease of rotation. After some discussion Messrs. Repsold proposed the plan which entirely avoids this, and which was ultimately approved and carried out as represented in the accompanying sketches.

Fig. 1 represents the "head" of the heliometer removed from the tube and viewed as if from the eye-end.

Fig. 2 represents a section of the head through the axis in a plane passing through the line of section of the object glass. S S, figs. 1 and 2, represent the scales.

From the eye-end of the telescope these scales are read by a long fixed microscope, of which the axis is indicated by the dotted line in fig. 2, which is marked "scale microscope."

For determining the errors of division of the scale the auxiliary microscope M M M is employed. This microscope slides in cylindrical bearings, of which the axis passes through the focal point of the object glass at right angles to the plane represented in fig. 2. In other words, the cylindrical bearings in which the division-error micrometer slides are planed and ground simultaneously with, and from the same centre as the bearings in which the mountings of the two segments of the telescopic object glass slide. The microscope is moved in the direction of the length of the scale by means of a rack and pinion motion, which is actuated by the milled head H. The scale is in the principal focus of an achromatic object glass of 20 mm. focal length, which renders parallel rays passing from

* More rigorously, one reckoning = 10″·024. The round number 10″ is retained throughout this paper as sufficiently exact for our purposes.

the scale through the prism of total reflection P; these rays are received by an achromatic objective of 73 mm. focus, which forms an enlarged image of the scale in the plane of the wires of the micrometer. Illumination of the scale is effected by reflection of the light of a small electric glow-lamp (passed through ground glass) from the surface of an elliptical reflector of parallel transparent glass which is placed between the prism and the objective of 73 mm. focus.

By turning the milled head H the observer can view a range of the scale $= \frac{2}{3}$ of its total length—that is, from the position of the prism P as represented in fig. 2 (in the position where the effective graduation begins) to the position of the same prism indicated by the dotted line p. This range permits the comparison of any part of one half of each scale with any part of either half of the other, and this, as will be afterwards shown, permits the complete determination of the errors of division of both scales.

The further details of the figures do not relate to the special problem in question, and are, besides, probably sufficiently obvious without further description.

In order to illustrate the actual *modus operandi*, let us suppose for simplicity that it is required to find the division errors of two similar scales, each divided into three parts. Let these divisions be numbered 0, 1, 2, 3 on one scale, and 10, 11, 12, 13 on the other.

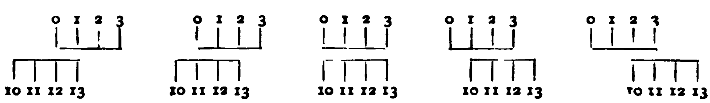


Fig. *a*. Fig. *b*. Fig. *c*. Fig. *d*. Fig. *e*.

The operation then divides itself into five series of observations.

For the first series the scales are moved from the position of fig. *c* (i.e. from the position of coincidence of the optical centres of the object glass) to the position shown in fig. *a*. Then, by means of the milled head H, the centre of the micrometer objective is brought over the divisions 0 and 12, and the readings of the micrometer, when division 0 and 12 are successively bisected, are taken; then, *without moving the relative position of the segments*, the micrometer objective is brought over the divisions 1 and 13 and similar readings are made.

Let m_{a0}, m_{a12}, m_{a1}, m_{a13} represent the micrometer readings on the divisions 0, 12, 1, and 13 respectively in series a, and let us suppose that the readings of the micrometer head increase as the webs move in the direction of increasing readings of the scale. Then we have

Excess of the length of the space (13 − 12) over the length of the space (1 − 0) ... ... $\Big\} = (m_{a13} - m_{a12}) - (m_{a1} - m_{a0}) = n_{a1}$

Next, the scales are set as in fig. *b*, and by quite a similar method of proceeding we get

$$\left.\begin{array}{l}\text{Excess of the length of the space}\\ \text{(12}-\text{11) over the length of the}\\ \text{space (1}-\text{0)} \ldots \quad \ldots \quad \ldots \quad \ldots\end{array}\right\} = (m_{b_{12}} - m_{b_{11}}) - (m_{b_1} - m_{b_0}) = n_{b_1}$$

$$\left.\begin{array}{l}\text{Excess of the length of the space}\\ \text{(13}-\text{12) over the length of the space}\\ \text{(2}-\text{1)} \quad \ldots \quad \ldots \quad \ldots \quad \ldots\end{array}\right\} = (m_{b_{13}} - m_{b_{12}}) - (m_{b_2} - m_{b_1}) = n_{b_2}$$

and so on similarly through the series *c*, *d*, and *e*, until each scale interval from 0 to 3 has been compared with each scale interval from 10 to 13.

The results may then be conveniently arranged as follows:—

$$\left.\begin{array}{cccc} & (13-12) & (12-11) & (11-10) \\ (1-0) & n_{a_1} & n_{b_1} & n_{c_1} \\ (2-1) & n_{b_2} & n_{c_2} & n_{d_1} \\ (3-2) & n_{c_3} & n_{d_2} & n_{e_1} \end{array}\right\} \quad \ldots\ldots \quad (3)$$

If we denote the excess of the length of the scale (3–0) over the mean length of the two scales by Δa, and the excess of (13–10) over the same mean by $\Delta\beta$ we obtain the length of each space as follows:—

$$\Delta\beta - \Delta a = n_{a_1} + n_{b_2} + n_{c_3} + n_{b_1} + n_{c_2} + n_{d_2} + n_{c_1} + n_{d_1} + n_{e_1} \quad . \quad . \quad (4)$$
$$\Delta\beta + \Delta a = 0$$

$$\left.\begin{array}{ll}\Delta(11-10) = \dfrac{n_{c_1} + n_{d_1} + n_{e_1}}{3} + \dfrac{\Delta a}{3} & \Delta(1-0) = -\dfrac{n_{a_1} + n_{b_1} + n_{c_1}}{3} + \dfrac{\Delta\beta}{3} \\ \Delta(12-11) = \dfrac{n_{b_1} + n_{c_2} + n_{d_2}}{3} + \dfrac{\Delta a}{3} & \Delta(2-1) = -\dfrac{n_{b_2} + n_{c_2} + n_{d_1}}{3} + \dfrac{\Delta\beta}{3} \\ \Delta(13-12) = \dfrac{n_{a_1} + n_{b_2} + n_{c_3}}{3} + \dfrac{\Delta a}{3} & \Delta(3-2) = -\dfrac{n_{c_3} + n_{d_2} + n_{e_1}}{3} + \dfrac{\Delta\beta}{3}\end{array}\right\} \quad . \quad (5)$$

of which the sums give our equation (4).

The corrections for division error are then

$$\left.\begin{array}{l}\text{For division—}\\ 11 = \Delta(11-10) \quad . \quad . \quad . \quad . \quad . \\ 12 = \Delta(11-10) + \Delta(12-11) \quad . \quad . \quad . \\ 13 = \Delta(11-10) + \Delta(12-11) + \Delta(13-12) \\ \text{For division—}\\ 1 = \Delta(1-0) \quad . \quad . \quad . \quad . \quad . \quad . \\ 2 = \Delta(2-1) + \Delta(1-0) \quad . \quad . \quad . \quad . \\ 3 = \Delta(3-2) + \Delta(2-1) + \Delta(1-0) \quad . \quad . \end{array}\right\} \quad \ldots\ldots \quad (6)$$

and these corrections are determined without cumulative error, because all the side equations are rapidly satisfied by the conditions of measurement.

The effective range of scale A of the Cape heliometer is graduated from 10^d to 190^d, and that of scale B from 210^d to 390^d, so that there is never any ambiguity as to the relative positions of the segments, or possibility of mistake as to which scale was read.

As the scale-division microscope has (from structural necessity) a range only equal to two-thirds of the length of the scale, it is only possible to compare the lower half of either scale with both halves of the other scale; and the scales were for purposes of examination considered to consist of four sections.

$$\text{Scale A}\begin{cases}\alpha = \ \ 10 \text{ to } 100\\ \beta = 100 \text{ to } 190\end{cases}$$

$$\text{Scale B}\begin{cases}\gamma = 210 \text{ to } 300\\ \delta = 300 \text{ to } 390\end{cases}$$

We can then compare any part of α with any part of γ and δ, and any part of γ with any part of α and β, but we cannot compare β and δ directly.

A complete solution is afforded by comparing

All subdivisions of α with all subdivisions of δ

" " γ " " β

The total length of α with the total length of γ

and this method gives all the division errors with equal weight with the minimum of labour.*

But it would try the observer's eyesight too severely to compare all the ninety subdivisions of α with the ninety subdivisions of γ at a single sitting (corresponding to series c in the previous example), nor could one rely on the constancy of the relative positions of the two slides between two or more sittings. I therefore determined, in the first place, to investigate only the errors of each 10th division, leaving the subdivisions of these intervals for investigation by subsequent series of measures.

The comparison of all subdivisions of α with those of δ, and of γ with those of β, were each made by four independent and complete series of observations, and the total length of α with that of γ was also determined by four sets of observations.

The reductions were carried out on the plan described above, with the mean results which are given in the following table. In order to enable the reader to estimate the accuracy of these mean results, the comparison of the mean result with each of the four independent determinations is given for each division.

* If we compare also all parts of α with all parts of γ we obtain the errors of the subdivisions of α and γ with double weight, and we cannot compare β and δ directly in order similarly to increase the weight of the determination of the subdivisions of these sections.

TABLE A.

	Division	Division Error from Mean of 4 Series.	Comparison of the Result of each Independent Series with the Mean.			
		″	″	″	″	″
α	10	0·000	...	...	...	...
α	20	+ ·067	−·028	+·012	+·003	+·013
α	30	+ ·083	−·018	±·000	−·006	+·024
α	40	+ ·238	−·009	+·009	−·002	+·002
α	50	+ ·146	−·005	+·005	−·002	+·002
α	60	+ ·048	−·002	−·002	±·000	+·004
α	70	+ 076	−·018	−·004	+·005	+·017
α	80	+ ·203	−·001	−·006	+·008	−·001
α	90	+ ·057	−·017	+·007	+·004	+·006
α	100	+ ·043	...	...	...	...
β	110	+ ·036	−·028	−·005	+·019	+·014
β	120	+ ·036	−·016	+·004	±·000	+·012
β	130	− ·026	−·018	+·009	+·009	±·000
β	140	− ·025	−·027	+·003	+·008	+·016
β	150	+ ·093	−·019	−·008	−·001	+·028
β	160	+ ·078	−·008	−·007	−·003	+·018
β	170	+ ·054	−·013	+·020	−·007	+·001
β	180	+ ·057	−·015	−·002	−·003	+·014
β	190	+ ·105	...	...	...	...
γ	210	0·000	...	...	...	...
γ	220	+ ·021	−·009	−·005	+·011	+·003
γ	230	+ ·051	+·012	+·001	−·019	+·006
γ	240	+ ·131	+·009	+·007	−·011	−·005
γ	250	+ ·016	−·011	+·001	+·021	−·011
γ	260	− ·133	−·014	−·005	+·023	−·004
γ	270	− ·060	−·014	+·005	+·011	−·002
γ	280	+ ·021	+·008	−·005	+·010	−·013
γ	290	− ·105	+·012	+·003	±·000	−·015
γ	300	− ·134	...	...	...	...
δ	310	− ·142	+·016	−·001	−·007	−·008
δ	320	− ·125	+·026	−·009	−·019	+·002
δ	330	− ·156	+·009	±·000	−·010	±·000
δ	340	− ·168	+·022	+·010	−·024	−·008
δ	350	− ·073	−·006	+·016	−·015	+·005
δ	360	− ·098	+·015	+·013	−·014	−·014
δ	370	− ·177	+·023	+·010	−·016	−·016
δ	380	− ·157	+·009	+·027	−·019	−·019
δ	390	− ·105	...	...	...	...

With these definitive results the original observations are represented as follows :—

TABLE B.

Comparison of α *and* δ. (*Excess of* δ.)

(O − C)

	390–380	380–370	370–360	360–350	350–340	340–330	330–320	320–310	310–300
	″	″	″	″	″	″	″	″	″
20–10	+0·003	−0·017	+0·013	+0·041	+0·002	−0·018	−0·014	−0·009	−0·003
30–20	− ·017	− ·009	− ·021	− ·017	+ ·007	+ ·017	+ ·018	− ·001	+ ·008
40–30	+ ·024	− ·027	− ·012	− ·039	− ·004	− ·009	+ ·017	− ·031	− ·010
50–40	− ·006	+ ·041	+ ·015	− ·017	− ·021	− ·018	+ ·029	+ ·007	− ·029
60–50	− ·025	+ ·017	− ·002	+ ·018	+ ·011	− ·021	− ·021	+ ·032	− ·007
70–60	− ·011	− ·010	− ·015	+ ·007	+ ·006	+ ·004	− ·002	+ ·018	+ ·007
80–70	+ ·040	+ ·013	+ ·004	+ ·018	+ ·002	− ·032	− ·041	− ·002	− ·006
90–80	− ·017	− ·020	− ·005	− ·005	+ ·022	+ ·043	− ·007	− ·020	+ ·017
100–90	− ·002	+ ·003	+ ·016	− ·018	− ·031	+ ·024	+ ·006	− ·001	+ ·007

Comparison of β *and* γ. (*Excess of* β.)

(O − C)

	190–180	180–170	170–160	160–150	150–140	140–130	130–120	120–110	110–100
	″	″	″	″	″	″	″	″	″
220–210	−0·009	−0·026	−0·008	+0·029	−0·010	+0·026	+0·014	±0·000	−0·019
230–220	+ ·009	+ ·022	− ·022	+ ·020	− ·004	+ ·037	− ·036	− ·005	− ·011
240–230	− ·001	+ .014	− ·020	+ ·006	− ·042	+ ·020	+ ·011	+ ·009	± ·000
250–240	± ·000	− ·007	− ·017	− ·006	+ ·007	± ·000	+ ·010	− ·003	+ ·021
260–250	+ ·015	+ ·014	+ ·014	− ·002	− ·009	− ·030	+ ·013	− ·020	+ ·005
270–260	− ·023	− ·012	+ ·010	− ·008	+ ·007	+ ·006	+ ·035	+ ·006	− ·002
280–270	+ ·014	− ·025	+ ·009	+ ·011	+ ·006	− ·045	− ·001	+ ·024	+ ·006
290–280	− ·013	+ ·014	+ ·004	− ·024	+ ·050	− ·014	− ·023	+ ·009	− ·001
300–290	+ ·016	+ ·010	+ ·026	− ·019	− ·007	− ·003	− ·029	− ·019	+ ·022

The probable error of the definitive results may be deduced either from the residuals of Table A or of Table B.

In the first case, the square of the *mean error* of the determination of a division error by a single series comes out

0·000182;

whence the *probable error* of the determination of each division from the mean of the four series is

±0″·0044.

Secondly, take the mean of the squares of the residuals in Table B, and divide this by nine, and we have the *mean error* of the determination of the length of each interval, and therefore,

if the errors are non-cumulative, this corresponds also with the *mean error* of division error, and accordingly we find the corresponding probable error to be also

$$\pm 0''.0044.$$

This affords a very crucial practical proof of the non-cumulative character of the errors of the process.

A less crucial but more evident proof is afforded by a glance at Table A, which shows that the four independent determinations of the middle divisions of the sections (50 or 60; 140 or 150; 250 or 260; 340 or 350) agree as well together as do the four independent determinations of division error near the beginning and end of α, β, γ, δ.

The linear value corresponding to the angular probable error is

$$0.000055 \text{ millimetre} = \frac{1}{500{,}000} \text{ inch (in round numbers).}$$

Such accuracy is the best proof of the exceeding sharpness of the divisions and the high perfection of the micrometric apparatus generally.

In the investigation of the errors of the single divisions now in progress, I content myself with two series of observations for the subdivision of each 10-division space. This will afford a probable error of

$$\pm 0''.0062$$

for the subdivision, or of

$$\sqrt{0.0044^2 + 0.0062^2} = \pm 0''.0076$$

for the probable error of the determination of the absolute division error of each single division.*

It may be contended that such accuracy is in excess of practical requirements; this question can only be considered by discussing the results of actual observations.

I have selected for the purpose of this discussion my measures of the distance of two stars from *β Centauri*, because they are all made within a comparatively short period of time and under a greater variety of hour-angle than those of any of the other stars which I am observing for parallax, except such as have been observed at periods six months apart; and as none have yet been observed at three such periods,† I have no means, therefore, of eliminating from the observations the effects of parallax and proper motion.

* The work, continued for an hour each day (it is undesirable, on account of the strain on the eyes, to work longer at a stretch, on division errors), requires about nine months for its completion, but it is a labour from which I do not shrink, in view of the importance of the determination in connection with the series of determinations in which the instrument is employed.

† The definitive researches on parallax were only begun on February 25, when the electric light arrangements were finally fitted.

The comparison stars are—

	Mag.	1875. R.A.	Decl.
		h m s	° ′
γ = Gould's Zones XIII. 2817	8	13 46 0	−60 43
δ = " " XIV. 258	8	14 3 56	−58 48

The stars are situated very symmetrically with respect to *β Centauri* both in distance and position-angle, and are therefore very suitable for discussing the probable error of observation as distinguished from that error affected by changes in the scale value. The following are the results of all the measures in question, converted into arc, from the scale and screw readings, with an assumed (approximately correct) constant screw value, and corrected only for refraction and aberration:—

1888.	Hour Angle.	Temperature.	γ	δ	$p-q$
	h m	°	″	″	°
June 7	+4 40	58 F.	5045·27	5380·05	137
8	−2 52	57	45·05	80·14	206
12	−2 37	56	45·02	79·95	292
17	−2 5	55	45·10	80·01	281
17	+4 2	50	45·15	80·13	145
18	−2 24	55	44·84	79·71	287
18	+3 48	50	44·88	79·68	148

The column marked $p-q$ gives the angle which the line joining the stars makes with the vertical at the mean epoch of observation, where p is the position-angle of the star γ with respect to *β Centauri*, and q the parallactic angle.

The sums and differences of the measured distances are

	$\delta+\gamma$	v	$\delta-\gamma$	v
	″	″	″	″
June 7	10425·32	+0·32	334·78	−0·13
8	5·19	+ ·19	5·09	+ ·18
12	4·97	− ·03	4·93	+ ·02
17	5·11	+ ·11	4·91	± ·00
17	5·28	+ ·28	4·98	+ ·07
18	4·55	− ·45	4·87	− ·04
18	4·56	− ·44	4·80	− ·11
Mean	10425·00		334·91	

and

$$\frac{vv}{n-1} = 0·1043 \text{ for } \delta+\gamma; \text{ and } 0·0114 \text{ for } \delta-\gamma;$$

hence the probable error of one observation is

$$\text{For } \delta+\gamma \pm 0''·218$$

$$\text{For } \delta-\gamma \pm 0''·072.$$

Of course in all refined observations it is only the *differences* that are employed, or else some other equivalent method is used to eliminate small inevitable changes in the scale value, due partly, perhaps, to inequalities of the temperature of different parts of the instrument, partly to physiological changes in the normal adaptation of the focus of the observer's eye.

Now a probable error of $\pm 0''\cdot 072$ in the measurement of the difference of the distances means a very high accuracy indeed in the determination of parallaxes, for the *difference* of the distances is affected by twice the parallax.

Suppose that a pair of comparison stars are found nearly in the major axis of the parallactic ellipse, and that four observations only are made, arranged at the times most suitable for parallax determination. These observations afford the equations

$$a - 0\cdot 5\Delta\mu - 2\pi = n_1$$
$$a \qquad + 2\pi = n_2$$
$$a \qquad + 2\pi = n_3$$
$$a + 0\cdot 5\Delta\mu - 2\pi = n_4.$$

Where a is a constant, $\Delta\mu$ the error of the assumed proper motion, and π the stars' parallax.

Their solution by least squares gives π with a weight=16, and therefore with a probable error

$$= \frac{\pm 0''\cdot 072}{\sqrt{16}} = \pm 0''\cdot 018$$

from *only four* observations.

If the observations are reduced in the same manner as is adopted by Professor Pritchard at Oxford, viz. to apply corrections proportional to the observed distances, such that the sum of the distances observed on the same day is a constant, then the following results are obtained:—

	γ	v	δ	v
	"	"	"	"
June 7	5045·11	+0·06	5379·89	−0·06
8	4·96	− ·09	80·04	+ ·09
12	5·03	− ·02	79·97	+ ·02
17	5·05	·00	79·95	·00
17	5·01	− ·04	79·99	+ ·04
18	5·06	+ ·01	79·94	− ·01
18	5·10	+ ·05	79·90	− ·05
Mean	5045·05		5379·95	

Reduced in this method (which is the method adopted by Professor Pritchard when he compares the Oxford photographic measures with heliometer observations) the *probable error of a single heliometer measure* is

$$\pm 0''\cdot 035,$$

or about one-third of the probable error of the best Oxford photographic results.

That such accuracy can be attained in the single measurement is sufficient argument for insisting on accuracy to $\pm 0''.01$, in the determination of the division errors, where the final result may rest not only upon a single observation but on many repeated observations in which the same divisions are employed.

The whole of the observations quoted in the preceding paper have been made by myself, but some independent measures of the same errors have been made by Mr. Finlay, which show no sensible difference in his results from mine. Indeed I am now convinced that the personality frequently found in the readings of scales and circles is due to the ragged character of the edges of the divisions; and, if in future the original graduations are made with a *cutting* diamond, and the "burrs" are removed by the process above described (instead of by the method of charcoaling), and if like linear perfection of the edges of the divisions is attained, personality in reading will disappear. I do not mean that personality will disappear in the *absolute* readings (for an observer may have a tendency to place the division too much to the right or left of the middle point between the parallel wires), but that it will disappear from the *difference* of the readings on two divisions.

It may be noted, finally, that the observations of *β Centauri* above quoted, as well as other researches which will afterwards be published, afford proof of the complete elimination of systematic error depending on the direction of measurement with respect to the vertical, which is secured by the use of the reversing prism.

Royal Observatory, Cape of Good Hope:
1888, *October* 15.

On Methods of printing Stellar Charts from Photographic Negatives. By Isaac Roberts.

Since the introduction of the "Stellar Pantograver" at the meeting of this Society in November last I have taken my negative of the 1,270 polar stars, which formed one of the illustrations to the descriptive matter concerning the instrument to Col. Sir C. W. Wilson, the director of the Ordnance Survey at Southampton, and explained to him the difficulties attendant upon the transference of the images of very faint stars from negatives on to paper so as to form reliable charts; and he readily and cordially undertook to try if the methods in use for printing the maps of the Government Survey would give satisfactory results with stellar photographs. The two sheets of illustrations which I present to the Society, and which are now before us, show the fine work that Sir C. W. Wilson has been able to execute from the negative by

his printing processes, and the results can now be compared with those obtained by aid of the pantograver.

There are eleven illustrations on each sheet, which may be described thus:—Five silver bromide prints, which were exposed to gaslight for the following intervals respectively: 20, 25, 30, 35, and 60 seconds each. Five platinotype prints, which were exposed to diffused sunlight for 3, 4, 5, 20, and 30 minutes respectively; and one photozincograph.

On the other sheet are five silver bromide prints reversed, the stars being black on a white ground. The duration of the exposures to gaslight were 1, 2, 3, 4, and 5 minutes respectively. Five platinotype prints, reversed like the bromide prints, and exposed to diffused sunlight for 25, 30, 35, 40, and 45 minutes respectively. One photozincograph, also reversed.

All the prints are remarkably sharp and clear, and obviously represent a state of perfection in instrumental, chemical, and manipulative skill that experience and ample resources can alone supply, and on the lines of the methods here illustrated it is not probable that more can be done than is here shown. Let us then compare the results with those obtained by the aid of the pantograver, and this can best be done by counting all the stars that are with certainty recognisable as such, without a magnifier, on each illustration; but, to shorten the process, I have counted the stars on three of the plates which show the largest number, with the following results: 452, 379, and 436 stars. I have also attached to the sheets two copies of the stars which were engraved with the pantograver, so that eye comparisons can readily be made. It will be evident on inspection, without the trouble of counting, that very large numbers of stars are missing from each print, and many others are reduced so that they cannot with certainty be identified as stars, and it would be impossible to measure with accuracy the stellar magnitudes on any of the prints. If any speck on the film of a negative should resemble a star it would of course print so that it could not be distinguished from a star; and on most negatives there are such specks more or less numerous.

If now we compare the foregoing results with those of the method of engraving we find the following advantages in favour of the latter:—

1. In the method of engraving, a magnifying power of about twenty-four diameters is used, and with it specks on the film are readily and with certainty distinguished from stars. The prints will therefore be free from these sources of error.

2. The engraving-instrument is made to proportionally *increase* the star diameter so that the faintest image on the film can be made visible to sight on the copper plate and on the print from it without altering the position of the centre. Accurate measurements of both positions and magnitudes of the stars can therefore be made from the engravings.

3. No star, however faint its image may be on the film, is lost on the engraving, except through the carelessness of the operator. In the comparison we are now making with the photographic prints, which have been made, as already stated, with the highest practical skill on zinc plates, nearly two-thirds of the faint stars are lost on a single plate which covers a sky space of two degrees in diameter, and many others are so small that we are in some doubt if they really are stars, and it is hopeless to try to determine their magnitudes with accuracy.

The conclusion, then, to which we are led at present is, that any known system of charting the stars directly from the original negatives by the aid of photographic prints fails to meet the essential conditions in number of the stars charted—in the mensurability of their magnitudes, and in freedom from liability of printing specks as stars; whereas the proposed system of engraving meets fully each condition and leaves the original negative uninjured for future reference.

Photographs of the Nebulæ in the Pleiades and in Andromeda. By Isaac Roberts.

The accompanying photograph* of the nebulæ in the *Pleiades* is an enlargement to four times the negative, taken on December 8, 1888, with exposure of the plate during four hours, and it brings to view all the nebulosity shown on the photographs which I have presented to the Society, and referred to at the meeting in January 1887 in a manner more clearly defined, though not exceeding the limits shown on those photographs. The nebulosity involves the following stars: *Asterope, Taygeta, Maia, Celæno, Electra, Alcyone*, stars 24,† 12, and far towards the *sp* of *Merope*. *Alcyone* is seen in the midst of a dense spiral nebula which branches in *np* direction towards and up to stars 9 and 8; and towards the north there are two faint circles of nebulous matter, one with its centre *np* star 15 and the other with its centre about midway between *Alcyone* and star 24. It is cut by a long nebulous streamer which extends both *p* and *f* star 24 and forms the chord of an arc. *Merope* is involved in dense streaky nebulosity, which extends far away in *sp* direction, where it fades gradually into the darkness of space. There is a crooked nebulous bridge connecting the *Merope* and *Alcyone* nebulæ, which passes over star 13. A nebulous straight line commences at star 7 and extends through star 1 in *p* direction till past the centre of *Electra*, where it ends. *Electra* has a horn-like projection from it, pointed towards *Alcyone*. *Maia* is involved in dense streaky nebulosity which extends to *Taygeta* and *Asterope* with a detached branch towards

* The photographs are placed in the Library. † Bessel's numbers.

and involving star 12, and also a horn-like projection in the direction of star *l*. There are also streaky masses of nebulosity trending north and south, filling the space between *Maia*, *Electra*, and *Merope*. There is a remarkable absence of symmetry between these nebulæ, that leads us to infer that we are looking at a number of separate nebulæ one behind the other in the line of sight, and two of them, which the nebulous straight lines represent, are seen edgewise. Many stars are visible through even the densest nebulosities.

We shall henceforward be able to study these objects by aid of reliable data when verbal or written descriptions will be better understood in giving the results of generalisations.

Nebula in Andromeda.

The accompanying photograph was taken on December 29, 1888, and is enlarged to three times the negative. The exposure was during four hours, and it confirms the various details shown upon the first photograph, which was presented to the Society at the last meeting, besides bringing to sight more clearly, by reason of the longer exposure, details that were either faint or absent upon the first. I am engaged in measuring the distances and angles between certain stars and the nuclei of the three nebulæ, together with the positions of some of the well-defined bright parts of the rings of the great nebula, so that in future any movement, orbital or otherwise, in their relative positions may be detected. When the measurements are completed they shall be presented to the Society.

The Surface of the Sun in 1888. By the Rev. S. J. Perry.

A few words will suffice to tell the history of solar changes during the past twelve months. More free from spots than in any previous year of the present decade, the Sun has still shown some signs of vigour and activity. On 241 days of the year observations were secured at Stonyhurst, and out of these the surface was found to be entirely free from spots on 102 days, and even faculæ were totally absent on 6 days. Throughout the year the faculæ were generally scarce and faint, but, when the definition was fairly good, it seldom happened that a few scattered bright markings could not be detected, although it might sometimes require a careful search to find them. Occasionally, however, a few bright scattered faculæ near the poles were the most striking feature of the Sun's surface. Comparing this year with those immediately preceding it, we find the percentage of spotless days to be greatly on the increase, having been 9·42 in 1886, 29·73 in 1887, and 42·32 in 1888. The greatest number of consecutive days during this minimum period, on which the spot-area never exceeded the one hundred thousandth part of the

visible hemisphere, was from May 24 to August 27, 1888, and the next longest succession of almost spotless days occurred during the autumn of 1886. In the month of January the solar disturbances consisted of small round spots of the normal type, but for the rest of the year small groups were more common than isolated spots, the principal member of the group being almost invariably followed by a number of lesser companions. In general, the spots did not last long, being for the most part very shallow disturbances.

Watching the general surface on days when the definition is unusually perfect, there does not seem to be much change from year to year, nor is there even a very marked difference between the appearance at a maximum and at a minimum period. The veiled spots continue to show themselves with great persistency in every portion of the surface, and the character and rapidity of their changes appear to be unaffected by the causes that produce the variations in the solar cycle. The sub-permanent veiled-spots, seen only within the spot-zones, have not been recorded more than twice or thrice during the last twelve months; but the slight penumbral markings, which start as ill-defined dots, and, quickly spreading out, congregate in considerable numbers so as to form large blurred patches, have often been seen most distinctly. The darkness of the shade in these markings is sometimes much more intense than usual, and not unfrequently these darker-veiled spots are observed in large numbers in the neighbourhood of scattered faculæ.

An observation of some importance was made on the day preceding the closing day of the year, and which I may perhaps be allowed here to recall, as it seems to indicate the commencement of a fresh solar cycle. The observation was the record of a small group of spots in the high latitude of 36° S, whereas spots have of late been confined within a rather narrow equatorial zone. If this group proves to be the forerunner of other spots similarly situated, we have fair grounds for concluding that a continual decrease in the mean spot-area, until the end of the present year, will be followed in 1890 by a rapid increase in the number and extent of solar disturbances.

Stonyhurst Observatory:
1889, *January* 9.

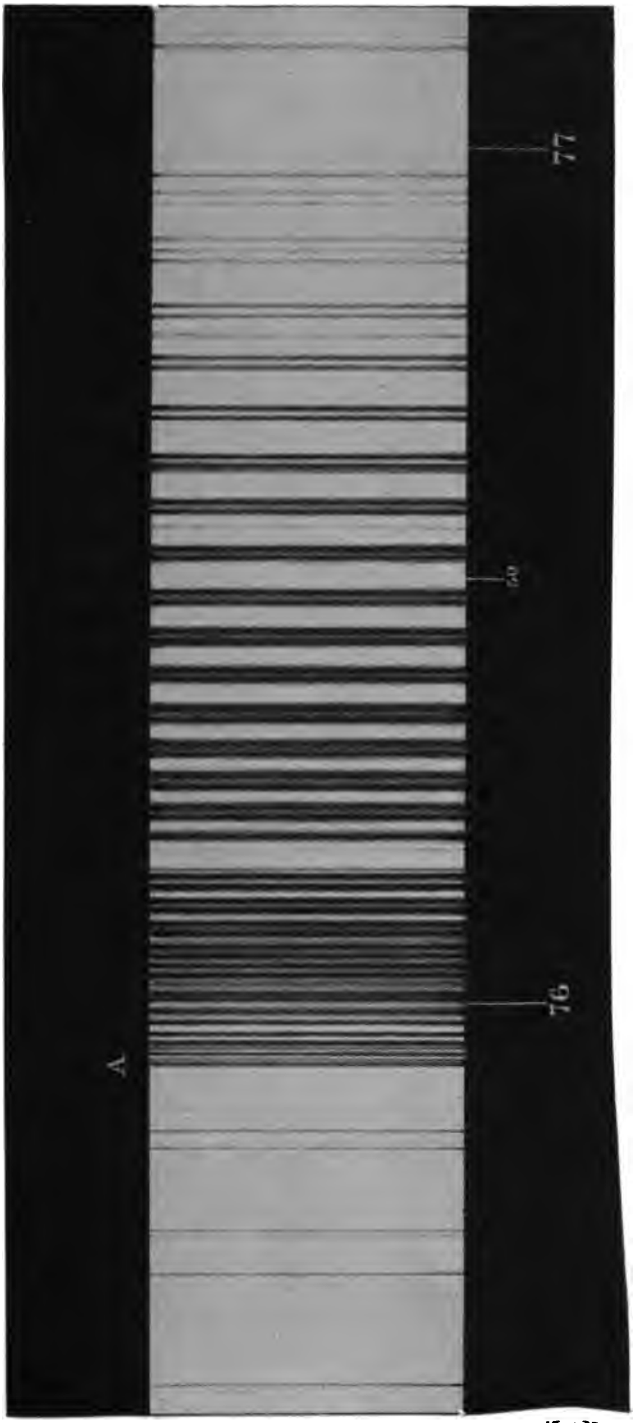
Photographs of the Red End of the Solar Spectrum from the Line (D) to the Line (A) in Seven Sections. Taken by F. McClean, M.A., F.R.A.S.

The accompanying photographs represent the red end of the solar spectrum from Fraunhofer line (D) to Fraunhofer line (A).

They comprise just one half of the visible spectrum from the line (H) to the line (A).

Dr. Rowland's published photographs of the solar spectrum

THE A GROUP of the SOLAR SPECTRUM.



Photographed by F. Mc Clean.

W.H. Wesley lith. West, Newman & Co

(excluding the ultra-violet spectrum beyond the line H) comprise the portion of the spectrum between wave-lengths 3,900 and 5,800 tenth metres (10^{-10} metres). The present photographs comprise from wave-length 5,800 (above D) to wave-length 7,700 (below A), or just as much again.

The sections, numbered from VII. to XIII., into which the photographs are divided, correspond to the sections of Ångström's normal solar spectrum—counting from the section containing (H) towards the red.

The scale of Section VII. (containing the line D) is the same as the same section of Ångström's Chart, but from this onwards the scale increases slightly along with the corresponding increase of the dispersion of the spectroscope employed. The spectroscope employed consists of a Rutherford Grating, ruled 17,296 lines to the inch, and about $1\frac{3}{4}$ inch square. The grating rotates, and the telescopes are fixed. The dispersion, therefore, increases as the secant of the angle of displacement of the grating from its central position. The increase in the scale of the photographs is about one-tenth from (D) to (A).

The red spectrum photographed is that of the second order. But besides the principal photographs of the sections of this spectrum, subsidiary photographs are given, showing, in the same sections, both the red spectrum of the second order as before, and also the overlapping, green to violet, spectrum of the third order. These double spectra were taken successively through the upper and lower portions of the same slit, and they serve as tests of the freedom of the red spectrum from the overlapping third order spectrum.

The positions of the leading divisions of the scale of wave-lengths are taken from Ångström's Chart. From (D) to (C) the scale is placed directly on the second order spectrum, while from (C) to (A) the scale is first applied to the subsidiary third order spectrum, and that of the second order spectrum obtained from it. Since the wave-lengths, at common points of the overlapping spectra, are strictly in the ratio of 3 to 2, these double spectra thus furnish an accurate scale to the obscurer parts of the red spectrum.

The present photographs are enlarged about $8\frac{1}{2}$ times from the original negatives. It must be remembered that the photographs of the green to violet portion of the third order spectrum, included in the subsidiary photographs, are not given as finished photographs of that portion of the spectrum. They are only given for the special purposes explained above. Their definition has, so far, suffered in the endeavour to obtain the two overlapping spectra on the same photograph. Also, the object-glasses at present employed in the spectroscope fail in bringing to a definite focus the image of the spectrum situated above the line G.

The principal photographs also need improvement in many respects, and they are only put forward in their present state

because they form, substantially, complete photographs of the red end of the solar spectrum such as have not hitherto been produced.

This paper is illustrated by a very faithful drawing by Mr. Wesley of the A group of lines, taken from the photographs. The photographs themselves have been placed in the Library.

1888, *December* 13.

Note on Observations of Nebulæ Spectra at Hurstside Observatory. By Albert Taylor.

The observations of nebulæ spectra recorded in this paper have been made at Sir Henry Thompson's Observatory (recently erected at Hurstside, West Molesey, Surrey) with a 12-inch refractor by Cooke, and a new star spectroscope by Hilger, specially adapted for observations of spectra of faint stars and nebulæ. The dispersive apparatus consists of a train of one 60° prism and two half-prisms, the half-prisms being attached to the lenses of the collimator and observing-telescope of the spectroscope. The micrometer is constructed so that one turn of the screw moves the cross-wires $\frac{1}{100}$th of an inch, and the drum being divided into 100 parts, readings can be made with accuracy to $\frac{1}{10000}$th of an inch, and by estimation to a smaller fraction than that.

The cross-wires of the micrometer can be illuminated at will by means of a small electric lamp. The eyepiece usually used for measurements has a power of 15, but a power of 10 was used for the nebula in *Lyra*.

The nebulæ examined were the Great Nebulæ in *Orion* and *Andromeda* and the Ring Nebula in *Lyra*.

The Great Nebula in Orion.

The spectrum of this nebula has been observed on every possible occasion during the last four months of 1888, and the results, while fully confirming Dr. Copeland's 'Observations' at Dun Echt, communicated to the Society in June 1888, also add several other lines which have not previously been recorded.

Previous to Dr. Copeland's observations, the visible spectrum of the Great Nebula was usually given as consisting of four bright lines and a faint continuous spectrum, the wave-lengths of the lines being given as 500, 495, 486, and 434. To these Dr. Copeland added 5874 (D_3), the position of which he had obtained from no less than 33 measurements, and a brightening at 447·6, seen only on one occasion. He found the continuous spectrum extending from 568 to 459·5, and showing "some indications of resolvability into lines or bands."

In September 1888, although the nebula was badly placed for observation, and daybreak interfered, measurements were made at

Hurstside Observatory of four bright lines in the green and blue, the positions being found to agree with those usually assigned. The continuous spectrum was easily seen on widening the slit. On October 13 the sky was exceptionally clear, and the spectrum of the nebula showed six bright lines, five of which had been previously seen by Dr. Copeland, viz. 500, 495, 486, 434, and D_3 (5873), the new line being at 470. The line 5873 was visible with a rather wide slit, and its position was fixed by micrometer readings and by comparison with the sodium (D) lines.

The 470 line was exceedingly faint, and measures were very difficult. The continuous spectrum extended from 460 to 570, and although there were evident irregularities in its intensity no positions of maximum brightness could be fixed. Later observations confirmed this appearance, and on October 27 a decided maximum was noted in the green above the 500 line. This was seen several times afterwards, but not until November 26 could its position be fixed as 520. November 26 and 27 were magnificently clear, especially the latter date, when all the bright lines previously observed were again measured, and in addition a line at 4470, and a maximum brightness of the continuous spectrum near the red end, the position of which was found to be 5592.

The bright lines observed in the nebula in *Orion* were therefore nine in number, their wave-lengths being 5872·6, 5592, 5200, 5001, 4953, 4863, 4703, 4470, 4340·5.

Since the end of November all the lines except 4470 and 5592 have been re-observed, but, considering the exceptional circumstances of November 27, it is not at all surprising that the excessively faint lines have not been visible since that date.

The 5001 line is by far the brightest in the spectrum, and is quite unlike any of the other lines in appearance. It is never seen sharp, but with the narrowest slit always has a fluffy appearance, this being much more marked on the blue than on the red edge. This was most carefully examined for evidence of structure, but the line was always found to be single, and no decided evidence of fluting structure could be made out. It may be that greater dispersion will show structure, but with the dispersion used here no structure could be seen. The F line was a little brighter than the 4953, and these two lines and the fainter hydrogen G (434) were always sharp and comparatively easy to measure. The 5872 is faint, but, being beyond the continuous spectrum, it is not so difficult to see as the 520. A rather wide slit is necessary to see these, but I have frequently seen them both with the slit sufficiently narrow to clearly separate the 5001 and 4953. Of the other lines 4706 has been most frequently seen, but the continuous spectrum and the faintness of the line render the measurements of position difficult. The 4470 and the 5592 were very faint indeed, and have not been seen since November 27, but then their positions were ascertained from four measurements of each.

When the 520 and 5592 were first measured it was thought that they and the 4706 were due to carbon in the nebula. Comparisons were made with the carbon flutings from a spirit-lamp and from a Bunsen's burner. The brightest carbon (517) does not agree with the 520 of the nebula, and the measurements of 520 are so decisive that it is impossible to believe that that brightness is due to the 517 carbon. A more probable explanation of the origin of the 5200 line or brightening is that it is due to magnesium, the 5001 and the 4706 being also due to that metal. It is interesting to note that the 470 line has been observed by Dr. Copeland in a planetary nebula which also contained 500, 495, and F (*Copernicus*, vol. i. p. 2). The 520 has been observed in comet *d* 1880 by Christie, and in comet *c* 1881 by Hasselberg, this line thus furnishing another spectroscopic connection between the comets and nebulæ. The D_3 line has not yet been definitely assigned to any substance, but it and the 559 may be due to manganese radiation; comparisons were tried, using manganese chloride heated in a Bunsen's burner, but, owing to the wide slit and the faintness of the lines in the nebula spectrum, no decisive results could be obtained. The 4863 and 4340 lines are undoubtedly the hydrogen F and G lines. C was searched for with the spectroscope specially adjusted for that line, but no trace of it could be found.

The results of the measurements on those dates when more measures than one were obtained are given in the wave-length table, the figures in brackets indicating the number of measurements made on each occasion. The numbers over the separate columns indicate the relative brightness of the lines; although 8 and 9 are so faint that it is almost impossible to say which is seen with least difficulty.

Table of Measurements of Lines in the Great Nebula in Orion.

Date. 1888.	5	9	6	1	3	2	7	8	4
Sept. 9	...	...	...	5002 (3)	4951 (3)	4863 (3)	...	...	4340 (1)
Oct. 13	5873 (6)	...	...	5000 (8)	4953 (8)	4863 (8)	4695 (3)	...	4340 (7)
Nov. 26	seen (0)	...	5200 (4)	5001 (4)	4954 (4)	4863 (4)	4703 (3)	...	4340 (4)
27	5872 (4)	5592 (4)	5200 (4)	5001 (4)	4952 (4)	4863 (4)	4706 (4)	4470 (4)	4342 (4)
Mean Values	5872·6	5592	5200	5001	4953	4863	4703	4470	4340·5

The continuous spectrum ends between 4703 and 4470 in the blue, and at about 570 in the citron.

The Great Nebula in Andromeda.

The spectrum of this nebula is usually recorded as perfectly continuous, but on October 5 and 9 I noticed in it a decided maximum in the green. Subsequent observations did not confirm this until November 30, when two maxima were visible, and five measures of their positions gave them as 5175 and 548; three measures on December 1 gave 5180 and 5467, and one on December 7 and 9 and two on the 12th gave 5170 and 547 as

the positions. The means, therefore, of the twelve measurements of each maximum show positions of 517·4 and 547·3. No other maximum has been measured, but on one occasion another was suspected down in the blue, although its position could not be fixed.

The Ring Nebula in Lyra.

This nebula has a monochromatic spectrum, and eight measurements at different times give a mean of 5002 as the position of the line. One other line has been suspected but not definitely measured.

Hurstside Observatory,
West Molesey, Surrey.

Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1888. *No. XII.*

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. xxxvi. p. 318, vol. xxxvii. p. 32, vol. xxxviii. p. 493, vol. xli. p. 109, vol. xlii. p. 230, vol. xliii. p. 81, vol. xliv. p. 89, vol. xlv. p. 330, vol. xlvi. p. 126, vol. xlvii. p. 101, and vol. xlviii. p. 116. The observations were made with the 'half-prism' spectroscope, one 'half-prism,' with a dispersion of about $18\frac{1}{2}°$ from A to H, being used throughout. A magnifying power of 14 was employed.

The cylindrical lens has always been used in front of the slit as in the observations made previously to 1881 and since 1882, March 14. The observations of the Sun, Moon, and planets have been made as a check on the general accuracy of the results.

The day specified in the first column is the civil day, and the hour is that of Greenwich civil time, commencing at Greenwich mean midnight, and reckoning from 0 to 24 hours.

The observations were made by Mr. Maunder throughout.

Motions of Stars in the Line of Sight in Miles per Second, observed with the Half-prism Spectroscope.

(+denotes Recession; −, Approach).

Date. 1888.			No of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
						γ Cassiopeiæ.		
		h						
Dec.	13	20	2	F	+ 8·0	+ 7·1	+ 10·2	Spectrum faint and very tremulous.
						Algol.		
Feb.	1	20	2	F	+17·1	−49·8	−52·0	Spectrum faint but steady,
Dec.	7	20	2	F	+ 6·4	−101·8	−120·0	Spectrum rather faint and tremulous; definition poor.

Date. 1888.		h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
						α Persei.		
Feb.	1	20	4	F	+15·5	−20·9	−16·8	Spectrum bright and steady; definition fair.
Dec.	7	20	2	F	+ 4·4	− 7·4	− 4·4	Spectrum fairly bright and steady; definition of star-line only fair.
						Aldebaran.		
Feb.	1	21	2	F	+16·9	+ 9·6	+21·5	Spectrum fairly bright and steady; star-line narrow and faint.
Dec.	7	23	2	F	+ 2·7	+27·9	+29·1	Spectrum bright and steady; star-line rather faint.
						Capella.		
Dec.	7	21	2	F	− 1·2	+30·2	+28·5	Spectrum bright and steady.
						Rigel.		
Feb.	1	21	4	F	+13·6	+11·0	+17·4	
Mar.	5	21	2	F	+16·0	+22·9	+20·5	Spectrum faint and very tremulous.
Dec.	7	23	2	F	+ 0·3	+25·5	+36·0	Spectrum tremulous but bright.
						β Tauri.		
Feb.	1	22	2	F	+14·7	− 7·7	+ 1·1	
Dec.	7	22	2	F	− 1·6	− 4·1	− 7·5	Star-line diffused but not very broad; spectrum seen well.
						γ Orionis.		
Feb.	1	22	4	F	+14·5	+ 1·5	+ 7·3	
Dec.	7	23	2	F	− 1·0	−25·6	−30·8	Spectrum fairly bright and steady; star-line faint.
						δ Orionis.		
Feb.	1	22	2	F	+13·6	+ 6·3	+14·4	Spectrum steady and fairly bright; star-line very faint.
						ε Orionis.		
Feb.	1	23	2	F	+13·3	−10·9	− 2·8	Spectrum bright and steady; star-line seen fairly well; definition good.
						ζ Orionis.		
Feb.	1	23	4	F	+13·0	−36·1	−41·0	Spectrum bright and fairly steady; star-line faint.
						β Aurigæ.		
Dec.	7	22	2	F	− 3·7	+32·5	+40·1	Spectrum faint, definition fair; star-line very broad and diffused.
						Sirius.		
Feb.	2	0	6	F	+ 7·3	−24·5	−24·5	Spectrum very bright but very unsteady.

Date. 1888.		No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
					Sirius.		
	h						
Mar.	5 22	6	F	+12·8	−37·4	−35·8	Spectrum bright but tremulous; star-line seen well.
Dec.	8 0	2	F	− 6·4	+17·9	+20·1	Spectrum bright but very tremulous; star-line very broad, ill-defined and diffused.
					Castor.		
Mar.	6 0	2	F	+15·4	− 6·9	− 5·3	Spectrum bright and steady; star-line dark but very broad and diffused.
	22 0	2	F	+17·4	− 0·4	− 0·6	Spectrum faint but fairly steady; star-line seen fairly well.
					Procyon.		
Mar.	5 23	4	F	+14·0	−17·7	−16·0	Spectrum bright and fairly steady; definition good; star-line seen well.
	21 23	2	F	+16·4	− 3·5	− 2·8	Spectrum faint and tremulous; star-line faint; definition bad; measures made with difficulty.
Dec.	8 0	2	F	−11·2	+25·8	+24·9	Spectrum bright and steady; star-line seen well.
					Pollux.		
Mar.	5 23	2	F	+15·0	−48·0	−47·5	Spectrum bright and steady; star-line faint; measures made with difficulty.
	21 23	2	F	+17·3	−43·3	−40·0	Spectrum faint and tremulous; star-line faint; definition bad; measures made with difficulty.
					Regulus.		
Mar.	22 0	2	F	+10·2	+ 2·9	+ 5·4	Spectrum fairly bright but tremulous; star-line seen fairly well.
May	7 22	2	F	+17·7	− 8·5	− 2·1	Spectrum fairly bright and steady; star-line very ill-defined and diffused.
					β Leonis.		
May	7 23	2	F	+14·9	+46·0	+47·7	Spectrum faint but steady; star-line dark but diffused.
					a Canum Venaticorum.		
May	23 22	2	F	+12·9	−44·7	−45·1	Spectrum fairly bright and steady; star-line well seen.
					Spica.		
May	7 23	2	F	+ 7·7	−31·2	−38·1	Spectrum fairly bright and steady; star-line not very broad, and but little diffused.
	23 23	2	F	+11·7	−38·3	−30·5	Spectrum very tremulous; star-line rather faint; measures made with difficulty.

Date. 1888.			No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
						Arcturus.		
		h						
May	7	23	2	F	+ 6·6	−37·5	−48·3	Spectrum bright and steady; star-line narrow but rather faint.
	23	23	2	F	+ 10·0	−41·0	−36·9	Spectrum very bright but rather tremulous; star-line faint, and seen with difficulty.
						γ Bootis.		
May	24	0	2	F	+ 8·5	−27·4	−27·8	Spectrum bright but rather tremulous; star-line faint and diffused; measures made with great difficulty.
						β Libræ.		
May	24	1	2	F	+ 4·7	−42·8	−42·3	Spectrum rather faint and tremulous; star-line ill-defined, and bisected with difficulty.
						α Coronæ Borealis.		
May	8	0	4	F	+ 1·6	+28·9	+42·4	Spectrum bright and steady; star-line dark and somewhat diffused.
	24	2	2	F	+ 4·9	+21·8	+19·3	Spectrum fairly bright and steady; definition good.
						α Ophiuchi.		
May	8	0	2	F	− 8·0	−24·5	−40·7	Spectrum fairly bright and steady; star-line broad and diffused.
						Vega.		
May	24	2	2	F	− 5·5	−39·3	−37·4	Spectrum bright and steady; star-line. well seen; definition good.
						Mars.		
May	7	23	5	F		+ 1·8	+ 2·1	Spectrum bright and steady. Computed motion, +3·7 miles per second.

Moon.

Date.			No of Meas.	Line.	Motion Measured.	Remarks.
		h				
Feb.	2	0	5	F	−0·3	The coincidence of the two spectra appeared perfect.
Mar.	21	22	5	F	−1·8	
May	24	0	5	F	−2·3	

Sun.

Dec.	10	13	5	F	+ 5·4	Direct comparison showed no perceptible want of coincidence between the two spectra, although the measures all gave the solar F line slightly to the red of the Hβ line.

Observations of Comet e 1888, made with the Transit Circle at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D. (corrected for Refraction, Parallax and R−D).	Remarks.
d h m s		h m s	° ′ ″	
1888, Dec. 22 6 34 59	A. P.	0 41 56·66	97 39 34·19	Cloudy.
26 6 8 30	T.	0 31 9·73	97 33 9·24	Scarcely visible.
31 5 37 44	T.	0 20 1·76	97 20 35·94	Very faint indeed; only a confused mist.
1889, Jan. 1 5 31 51	L.	0 18 4·56	97 17 36·98	Very faint.

The observations were made in a dark field with wires illuminated.

The initials T., L. and A. P., are those of Mr. Thackeray, Mr. Lewis, and Mr. A. Pead.

The observations of this comet, printed in vol. xlix. p. 83, are not corrected for R−D. The corresponding corrections to N.P.D. are for November 27 and December 1 $+0''\cdot55$; for December 5, 7, and 12, $+0''\cdot56$.

Observations of Occultations of Stars by the Moon and Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1888.

(Communicated by the Astronomer Royal.)

Occultations of Stars by the Moon.

Day of Obs.	Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1888, Jan. 28 (*a*)	Disapp.	No. 157	S.E. Equat.	220	Eclipsed	10 33 49·94	M.
28	„	165	Cooke Equat.	200	„	10 42 32·00	H.
28	„	180	Lassell Refl.	170	„	10 52 2·85	H. T.
28	„	180	Cooke Equat.	200	„	10 52 3·45	H.
28 (*b*)	„	181	Lassell Refl.	170	„	11 1 23·35	H. T.
28	Reapp.	126	Lassell Refl.	170	„	11 3 33·35	H. T.
28 (*c*)	„	126	S.E. Equat.	220	„	11 4(18·74)	M.
28	„	126	Cooke Equat.	200	„	11 3 33·12	H.
28 (*d*)	„	128	Lassell Refl.	170	„	11 7 (0·35)	H. T.
28 (*e*)	„	128	Cooke Equat.	200	„	11 6 11·42	H.
28	Disapp.	201	Lassell Refl.	170	„	11 27 34·35	H. T.
28 (*f*)	„	210	Cooke Equat.	200	„	11 27 32·43	H.
28	Reapp.	157	Lassell Refl.	170	„	11 34 23·85	H. T.
28	„	157	Corbett Refr.	110	„	11 34 24·95	L.
28 (*g*)	„	150	Lassell Refl.	170	„	11 37 39·35	H. T.
28	„	164	Lassell Refl.	170	„	11 54 3·55	H. T.

Day of Obs.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1888, Jan. 28 (*h*)	Reapp. 164	S.E. Equat.	200	Eclipsed	11 54 13·64	M.
28	„ 164	Corbett Refr.	110	„	11 54 4·85	L.
28 (*i*)	„ 165	S.E. Equat.	200	„	11 55 1·54	M.
28	„ 181	Lassell Refl.	170	„	11 59 20·35	H. T.
28	„ 180	Lassell Refl.	170	„	12 4 35·55	H. T.
28 (*j*)	„ 180	S.E. Equat.	200	„	12 4 42·24	M.
28	„ 180	Corbett Refr.	110	„	12 4 36·55	L.
May 20	Disapp. *b* Virginis	Altaz.	100	Dark	12 55 33·75	H.
24 (*k*)	„ η Libræ	Altaz.	100	„	10 51 40·37	A. D.
July 19 (*l*)	„ Piazzi XVI. 236	Altaz.	100	„	10 26 34·00	T.
23 (*m*)	Reapp. 20 Capricorni	E. Equat.	70	Bright	10 47 7·25	H. T.
Oct. 20	Disapp. μ Ceti	E. Equat.	140	„	11 38 53·26	A. D.
20 (*n*)	„ μ Ceti	Altaz.	100	„	11 38 (28·38)	J. P.

The Nos. of the stars observed on the occasion of the total eclipse of the Moon, January 28, are taken from the catalogue of stars printed and circulated by Professor Struve.

Notes.

(*a*) Doubtful if occulted by the Moon or hidden by cloud. (*b*) Observation doubtful.
(*c*) Doubtful if the reappearance was from behind the Moon or cloud. (*d*) Observation doubtful.
(*e*) Observed a bright speck slightly within the Moon's limb; sky clouded over immediately.
(*f*) The star seemed to touch the Moon's limb, and get rapidly fainter, 10^s before it disappeared.
(*g*) Observation doubtful. (*h*) Reappearance instantaneous and well observed.
(*i*) It is believed that the real occultation was observed, although the Moon was partly hidden by cloud at the time.
(*j*) Clouds passing. (*k*) Observation difficult, owing to faintness of the star before disappearance.
(*l*) Star faint. (*m*) Very faint when first seen. (*n*) Observation doubtful.

Phenomena of Jupiter's Satellites.

Day of Obs.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1888, Jan. 5	III.	Ecl. R. First seen	Altaz.	100	17 38 9	17 38 2	H. T.
Apr. 18 (*a*)	III.	Tr. Ing. First contact	E. Equat.	210	16 12 43	16 22	"
18	III.	Bisection	"	"	16 20 13		"
29 (*b*)	III.	Occ. R. First seen	"	"	11 7 58	11 8	L.
29	III.	Last contact	"	"	11 15 47		"
May 5	II.	Ecl. D. Began to fade	Altaz.	100	11 34 35	11 43 33	A. D.
5	II.	Last seen	"	"	11 42 33		"
5 (*c*)	II.	Occ. R. First seen	Lassell Refl.	310	14 51 13	14 55	H. T.
9	I.	Ecl. D. Began to fade	E. Equat.	210	10 54 31		L.
9	I.	Bisection	"	"	10 56 26	10 59 13	"
9	I.	Last seen	"	"	10 58 37		"
10 (*d*)	I.	Tr. Egr. First contact	"	70	10 32 58	10 33	A. D.
10	I.	Last contact	"	"	10 35 48		"
12	II.	Ecl. D. Began to fade	"	"	14 14 40	14 18 42	T.
12	II.	Last seen	"	"	14 18 4		"
24	III.	Tr. Egr. Bisection	Altaz.	100	10 26 5	10 29	A. D.
24	III.	Last contact	"	"	10 30 20		"
31	III.	Tr. Ing. First contact	Lassell Refl.	280	12 4 37		H. T.
31	III.	Bisection	"	"	12 11 52	12 12	"
31	III.	Last contact	"	"	12 20 7		"

Day of Obs.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1888, June 1	I.	Occ. D. First contact	E. Equat.	140	10 47 30		A. D.
1	I.	Bisection	,,	,,	10 51 14	10 52	,,
1	I.	Last seen	,,	,,	10 54 39		,,
2	I.	Tr. Egr. First contact	Altaz.	100	10 8 42	10 12	T.
2	I.	Last contact	,,	,,	10 11 47		,,
6	II.	Occ. D. First contact	E. Equat.	210	10 32 21		,,
6	II.	Bisection	,,	,,	10 35 51	10 36	,,
6	II.	Last seen	,,	,,	10 38 25		,,
24	I.	Occ. D. First contact	,,	,,	10 27 0		A. D.
24	I.	Bisection	,,	,,	10 31 29		,,
24	I.	Last seen	,,	,,	10 35 29	10 34	,,
24	I.	First contact	Lassell Refl.	280	10 26 48		L.
24	I.	Last seen	,,	,,	10 36 3		,,

Notes.

(*a*) Limb of *Jupiter* very tremulous. Daylight rather strong.
(*b*) Observation unsatisfactory; limb of *Jupiter* very badly defined.
(*c*) Observation considered doubtful; *Jupiter* partly hidden by a tree; image extremely bad.
(*d*) Image of *Jupiter* very bad; observation uncertain.

The clear aperture of the mirror of the Lassell Reflector is 24 inches, of the object-glass of the S.E. Equatorial 12·8 inches, of the E. Equatorial 6·7 inches, of the Corbett Refractor 6½ inches, of the Cooke Equatorial 6 inches, and of the Altazimuth 3¾ inches.

The initials H. T., A. D., T., M., L., H., and J. P., are those of Mr. Turner, Mr. Downing, Mr. Thackeray, Mr. Maunder, Mr. Lewis, Mr. Hollis, and Mr. Power respectively.

1889, *January* 7.

Étoiles filantes de la période du 9–11 août 1888, observées en Italie. Par F. Denza.

(*Communicated by the Secretaries.*)

J'ai achevé la discussion et le calcul des observations faites dans les stations italiennes sur la pluie météorique des *Perseides*, et j'en donne ici un résumé.

Pour rendre les résultats en quelque manière comparables entre eux, je fais suivre une table, dans laquelle se trouvent les résultats obtenus, dans chaque station, pendant les nuits du 9, 10 et 11 août, qui sont les plus importantes de la période, par un seul observateur pendant l'espace d'une heure.

Numéro horaire des étoiles filantes observé dans chaque station pendant les nuits du 9, 10 et 11 août.

Stations.	Nuits. 9	10	11	Stations.	Nuits. 9	10	11
Recoaro	4	7	1	Doria (Gênes)	36	55	33
Roverbella (Mantoue) ...	11	9	12	Bargone (Emile)... ...	9	9	10
Mantoue	3	15	3	Modène	10	12	10
Crémone	6	6	9	Correggio (Emile) ...	12	13	13
Vocca (Valsesia)	16	33	13	Castel Maggiore ...	25	40	13
Fara (Novare)	24	32	25	Pistoia	35	55	49
Viguarello (Novare) ...	10	28	20	Florence	17	34	30
Aprica (Valteline) ...	9	13	8	Ponte Badia (Florence)...	9	8	20
S. Giovanni Canarese ...	3	6	5	Fiesole (Florence) ...	9	25	25
Pettinengo (Bielle) ...	18	19	2	Maenza (Rome)	40	25	52
Savillan	9	9	5	S. Giovanni in Galilea ...	14	17	24
Sommariva Perno ...	17	19	17	S. Martino in Pensili ...	15	22	16
Moncalieri	13	18	8	Gaète	16	13	20
Volpeglino (Tortone) ...	24	38	13	Valle di Pompei (Naples)	9	19	9
				Palagonia (Catane) ...	6	13	8

De ce prospectus résulte que les donnés des diverses stations diffèrent beaucoup entre eux. Cette différence a été causée par plusieurs circonstances, telles que la différente transparence du ciel, qui toutefois fut en général serein, la diverse pratique des observateurs, la différente attention usée par ceux-ci dans le tracement des trajectoires, la diversité de l'heure d'observation et aussi le moyen divers dans lequel se manifesta l'apparition. C'est pourquoi nous nous proposons, pour l'année prochaine, de régler ces observations uniformement.

Toutefois, du prospectus que nous avons donné, on voit que, dans la plupart des observatoires, le maximum se vérifia pendant la nuit du 10 au 11. Très petit est le nombre des stations, où le maximum des météores a été observé dans la nuit du 11 au 12. Elles ne font que 4 sur 29, et ce sont 4 aussi celles,

dont les résultats obtenus le 10 et le 11 diffèrent très peu entre eux ; en sorte que nous pouvons affirmer que le maximum de l'apparition fut observé, comme nous l'avons déjà dit, dans la nuit du 10 au 11.

Dans son ensemble la pluie des étoiles filantes a été assez abondante, comparativement à celles des années passées.

La splendeur et la beauté des météores furent plus ou moins rémarquables selon les lieux d'observations. Le radiant principal de la période ne différa que très peu de l'ordinaire, auprès de l'η de *Persée*, et du moyen des divers trajectoires dans plusieurs stations ; sa position résulte en

$$\alpha=43^\circ,\ \delta=+56^\circ.$$

Comme à l'ordinaire, outre ce radiant principal, on en observa plusieurs autres, surtout dans le *Cygne*, en *Andromède*, dans le *Dragon*, dans l'étoile polaire et ailleurs. Les plus importants sont les suivants :—

1 — $\alpha=296^\circ$, $\delta=+53^\circ$, près de γ *Cygni*,

2 — $\alpha=292$, $\delta=+68$, près de δ *Draconis*,

3 — $\alpha=\ \ 3$, $\delta=+30$, près de α *Andromedæ*

4 — $\alpha=\ 15$, $\delta=+89$, près de la *Polaire*.

Plusieurs bolides ont été observés dans nos stations.

De l'Observatoire de Moncalieri :
1888, 24 *Décembre.*

Note on an Error in Mr. Chambers's "Working Catalogue of Red Stars." By Dr. J. Holetschek.

(*Extract from a letter to the Secretary.*)

Permit me to point out an error in the "Working Catalogue of Red Stars," by G. F. Chambers (*Monthly Notices*, vol. xlvii. p. 384).

I have shown in the *Astr. Nachr.* No. 2656 (Band 111, p. 255) that the object given as No. 586 in Birmingham's Catalogue of Red Stars does not exist in the heavens, but has only been placed in that catalogue in consequence of a mistake of Secchi's. Birmingham has taken the place of the star in question from Secchi's "Prodromo di un Catalogo fisico delle stelle colorate," in which this object bears the number 403. We find in Secchi's paper, "Sugli spettri prismatici delle stelle fisse," Memoria II., which was evidently made use of in the compilation of the "Prodromo," the following particulars on page 58:

Schj. No. 253 $\alpha=21^h\ 30{\cdot}2^m$ $\delta=+58^\circ\ 8'$ var.

This is, however, as may be seen from a glance at Schjellerup's "Catalog der rothen isolirten Sterne" (*Astr. Nachr.* No. 1591), nothing else than W. Herschel's "Garnet Star," but the minute of right ascension should be 39·2, instead of 30·2.

Secchi has, however, given in the "Prodromo," not only the correct, but also the incorrect position, and thus out of *one* red star has made *two*. The object Secchi No. 403=Birmingham No. 586=Chambers No. 648 should therefore be struck out.

Vienna: 1889, *Jan.* 14.

Ephemeris for Physical Observations of the Moon. By A. Marth.

1889, *April* 1 *to June* 30.

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Amount.	Direction.
	°	°	°	°	°	°
April 1	277·98	−1·52	+3·98	+6·49	7·61	328·6
2	290·20	1·52	3·31	6·17	7·00	331·9
3	302·42	1·52	2·40	5·57	6·06	336·8
4	314·64	1·52	+1·28	4·72	4·89	344·9
5	326·85	1·53	0·00	3·68	3·68	0·1
6	339·05	1·53	−1·39	2·48	2·84	29·1
7	351·25	−1·53	−2·79	+1·18	3·02	67·0
8	3·45	1·54	4·11	−0·18	4·12	92·5
9	15·64	1·54	5·26	1·56	5·49	106·5
10	27·83	1·54	6·16	2·89	6·80	115·2
11	40·01	1·54	6·70	4·11	7·86	121·7
12	52·18	1·54	6·81	5·17	8·54	127·3
13	64·35	1·54	6·47	5·97	8·79	132·8
14	76·52	−1·53	−5·68	−6·44	8·58	138·8
15	88·69	1·53	4·49	6·53	7·92	145·6
16	100·85	1·52	3·02	6·21	6·90	154·1
17	113·02	1·52	−1·40	5·46	5·64	165·7
18	125·19	1·51	+0·23	4·35	4·35	183·1
19	137·37	1·50	1·74	2·95	3·43	210·5
20	149·55	1·49	3·04	−1·38	3·34	241·6
21	161·74	−1·48	+4·09	+0·26	4·09	273·6
22	173·94	1·47	4·85	1·85	5·18	290·9
23	186·14	1·46	5·35	3·30	6·28	301·7
24	198·35	1·45	5·61	4·54	7·21	309·1
25	210·57	1·43	5·65	5·51	7·89	314·4
26	222·79	1·42	5·50	6·18	8·26	318·5
27	235·02	1·41	5·14	6·53	8·30	321·9
28	247·25	−1·40	+4·62	+6·55	8·01	325·0
29	259·49	1·39	3·90	6·26	7·37	328·2
30	271·73	1·38	2·99	5·68	6·42	332·3

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Amount.	Direction.
		°	°	°	°	°	°
May	1	283·96	1·37	1·90	4·85	5·21	338·6
	2	296·19	1·36	+0·67	3·82	3·88	350·0
	3	308·42	1·35	−0·68	2·62	2·71	14·5
	4	320·65	1·34	2·10	+1·32	2·48	57·8
	5	332·88	−1·33	−3·52	−0·04	3·54	96·7
	6	345·10	1·32	4·85	1·41	5·06	106·3
	7	357·31	1·31	6·02	2·74	6·62	114·5
	8	9·52	1·30	6·93	3·97	7·99	119·9
	9	21·73	1·29	7·50	5·05	9·03	124·1
	10	33·93	1·27	7·63	5·90	9·63	127·9
	11	46·12	1·26	7·28	6·45	9·72	131·8
	12	58·31	−1·24	−6·46	−6·66	9·27	136·0
	13	70·49	1·22	5·18	6·45	8·26	141·4
	14	82·67	1·20	3·54	5·81	6·80	148·8
	15	94·85	1·18	−1·67	4·76	5·05	160·8
	16	107·03	1·16	+0·26	3·38	3·39	184·5
	17	119·21	1·14	2·10	1·76	2·74	230·0
	18	131·40	1·12	3·72	−0·05	3·72	269·3
	19	143·59	−1·10	+5·04	+1·64	5·30	288·1
	20	155·79	1·08	5·99	3·19	6·78	298·1
	21	168·00	1·05	6·59	4·51	7·98	304·5
	22	180·22	1·03	6·85	5·54	8·80	309·1
	23	192·44	1·01	6·79	6·25	9·22	312·8
	24	204·67	0·99	6·46	6·64	9·25	315·9
	25	216·90	0·97	5·89	6·69	8·90	318·8
	26	229·14	−0·95	+5·11	+6·43	8·20	321·7
	27	241·38	0·93	4·14	5·88	7·19	325·0
	28	253·62	0·91	3·02	5·07	5·90	329·3
	29	265·87	0·89	1·77	4·05	4·42	336·4
	30	278·12	0·87	+0·42	2·86	2·89	351·6
	31	290·36	0·85	−0·98	1·54	1·83	32·5
June	1	302·61	0·83	2·41	+0·16	2·42	86·1
	2	314·85	−0·81	−3·80	−1·23	4·00	107·9
	3	327·09	0·79	5·10	2·58	5·71	116·9
	4	339·32	0·77	6·22	3·84	7·31	121·8
	5	351·55	0·75	7·11	4·94	8·65	124·9
	6	3·77	0·73	7·69	5·84	9·64	127·4
	7	15·99	0·71	7·86	6·46	10·16	129·6

$u-U$, orbital longitudes of the satellites reckoned from the points which are in superior conjunction with the planet or in opposition to the Earth.

$U+180°$, planeto-centric longitude of the Earth reckoned in the assumed plane of the orbits from the ascending node on the celestial equator.

B, latitude of the Earth above the plane of the orbits, the ascending node N and inclination J, of which, in reference to the equator of 1880·0, are assumed to have the values

$$N = 165°{\cdot}770; \quad J = 75°{\cdot}210, \text{ or}$$
$$\text{for } 1889{\cdot}0 \quad 165°{\cdot}898 \quad 75°{\cdot}198.$$

The values of P, a, b, and $u-U$ are to be interpolated directly for the times for which the apparent positions are required, the equation of light being already taken into account. The degrees of the differences of successive values of $u-U$ are in the case of *Ar.* 1428°, *Um.* 868°, *Tit.* 413°, *Ob.* 267°. The position-angles p and distances s are then found by means of the formulæ

$$s \sin(p-P) = a \sin(u-U),$$
$$s \cos(p-P) = b \cos(u-U).$$

The satellites will be at their greatest elongations (N. in position-angle $P+90°$, S. in position $P-90°$) and at their conjunctions (superior conjunction in position-angle P, inferior conjunction in position $P-180°$) with the planet's centre at the following hours, Greenwich mean times:—

Ariel.

	N. Elong.		S. Elong.		N. Elong.		S. Elong.		N. Elong.		S. Elong.
1889.	h		h		h		h		h		h
Feb. 27	23·3	M. 1	5·5	Apr. 9	7·1	10	13·4	May 19	15·0	20	21·3
Mar. 2	11·8	3	18·0	11	19·6	13	1·9	22	3·5	23	9·8
5	0·3	6	6·5	14	8·1	15	14·4	24	16·0	25	22·3
7	12·7	8	19·0	16	20·6	18	2·8	27	4·5	28	10·8
10	1·2	11	7·5	19	9·1	20	15·3	29	17·0	30	23·3
12	13·7	13	20·0	21	21·6	23	3·8	June 1	5·5	2	11·7
15	2·2	16	8·5	24	10·1	25	16·3	3	18·0	5	0·2
17	14·7	18	20·9	26	22·6	28	4·8	6	6·5	7	12·7
20	3·2	21	9·4	29	11·1	30	17·3	8	19·0	10	1·2
22	15·7	23	21·9	May 1	23·6	3	5·8	11	7·5	12	13·7
25	4·2	26	10·4	4	12·1	5	18·3	13	20·0	15	2·2
27	16·7	28	22·9	7	0·6	8	6·8	16	8·5	17	14·7
30	5·2	31	11·4	9	13·0	10	19·3	18	21·0	20	3·2
Apr. 1	17·6	2	23·9	12	1·5	13	7·8	21	9·5	22	15·7
4	6·1	5	12·4	14	14·0	15	20·3	23	22·0	25	4·2
6	18·6	8	0·9	17	2·5	18	8·8	26	10·4	27	16·7

Umbriel.

1889.	N. Elong. h		S. Elong. h		N. Elong. h		S. Elong. h		N. Elong. h		S. Elong. h
Feb. 28	21·9	M. 2	23·6	Apr. 11	8·6	13	10·3	May 22	19·3	24	21·0
Mar. 5	1·3	7	3·1	15	12·0	17	13·8	26	22·7	29	0·5
9	4·8	11	6·5	19	15·5	21	17·2	31	2·2	J. 2	3·9
13	8·3	15	10·0	23	19·0	25	20·7	June 4	5·7	6	7·4
17	11·7	19	13·5	27	22·4	30	0·2	8	9·1	10	10·9
21	15·2	23	16·9	May 2	1·9	4	3·6	12	12·6	14	14·3
25	18·7	27	20·4	6	5·4	8	7·1	16	16·1	18	17·8
29	22·1	31	23·9	10	8·8	12	10·6	20	19·6	22	21·3
Apr. 3	1·6	5	3·3	14	12·3	16	14·1	24	23·0	27	0·8
7	5·1	9	6·8	18	15·8	20	17·5	29	2·5	Jy. 1	4·2

Titania.

	h			h		h			h
Feb. 26	8·9	inf.	Apr. 2	4·8	May 7	0·7	inf.	June 10	20·6
28	13·1	S.	4	9·0	9	4·9	S.	13	0·8
Mar. 2	17·3	sup.	6	13·2	11	9·2	sup.	15	5·1
4	21·6	N.	8	17·5	13	13·4	N.	17	9·3
7	1·8	inf.	10	21·7	15	17·7	inf.	19	13·6
9	6·1	S.	13	2·0	17	21·9	S.	21	17·8
11	10·3	sup.	15	6·2	20	2·1	sup.	23	22·0
13	14·6	N.	17	10·5	22	6·4	N.	26	2·3
15	18·8	inf.	19	14·7	24	10·6	inf.	28	6·5
17	23·0	S.	21	19·0	26	14·9	S.	30	10·7
20	3·3	sup.	23	23·2	28	19·1	sup.	July 2	15·0
22	7·5	N.	26	3·5	30	23·4	N.	4	19·2
24	11·8	inf.	28	7·7	June 2	3·6	inf.	6	23·5
26	16·0	S.	30	11·9	4	7·9	S.	9	3·7
28	20·3	sup.	May 2	16·2	6	12·1	sup.	11	7·9
31	0·5	N.	4	20·4	8	16·4	N.	13	12·2

Oberon.

	h			h		h			h
Feb. 27	10·4	sup.	Apr. 8	20·0	May 19	5·6	sup.	June 28	15·1
Mar. 2	19·2	N.	12	4·8	22	14·4	N.	July 1	23·9
6	4·0	inf.	15	13·6	25	23·2	inf.	5	8·7
9	12·8	S.	18	22·4	29	8·0	S.	8	17·5
12	21·6	sup.	22	7·2	June 1	16·8	sup.	12	2·4
16	6·4	N.	25	16·0	5	1·6	N.	15	11·2
19	15·2	inf.	29	0·8	8	10·4	inf.		
23	0·0	S.	May 2	9·6	11	19·2	S.		
26	8·8	sup.	5	18·4	15	4·0	sup.		
29	17·6	N.	9	3·2	18	12·8	N.		
Apr. 2	2·4	inf.	12	12·0	21	21·5	inf.		
5	11·2	S.	15	20·8	25	6·3	S.		

Titania and *Oberon* will appear in the same direction from the centre of the planet:—

		h			h			h
Mar.	8	17·8	Apr.	27	0·4	June	15	7·1
Apr.	2	9·1	May	21	15·7	July	9	22·4

and in opposite directions:

		h			h			h
Feb.	24	10·2	Apr.	14	16·7	June	2	23·4
Mar.	21	1·5	May	9	8·1		27	14·8

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. FEBRUARY 8, 1889. No. 4

W. H. M. CHRISTIE, M.A., F.R.S., President, in the chair.

William Henry Fisher Alexander, B.A., 26 Bousfield Road, St. Catherine's Park, S.E.;
John Cockburn, 32 St. Andrew Square, Edinburgh;
Thomas Keig, Prospect Hill, Douglas, Isle of Man;
Arthur Courtauld Willoughby Lowe, B.A., Gosfield Hall, Halstead, Essex, and 76 Lancaster Gate, Hyde Park, W.;
Arthur B. P. Mee, Llanelly, Carmarthenshire;
Captain Archibald T. Miller, R.N., H.M.S. *Conway*, Birkenhead; and
Kenneth James Tarrant, Letchford House, Hatch End, Pinner,

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-NINTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1887	226	365	3	594	48	1	643
Since elected	+8	+19	...	...	...	...	...
Deceased	−7	−7	...	...	−1	...	...
Resigned	...	−12	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...
Removals	+3	−3	...	...	...	...	...
December 31, 1888	230	360	3	593	47	1	641

[The Associate referred to died in 1883, but his death was not known till the present year.]

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, January 1, 1888:—						
Balance at Bankers', as per pass book ...	327	14	1			
" on Suspense Account	2	2	0			
" in hand of Assistant Secretary on account of Turnor and Horrox Funds	5	19	8			
" in hand of Assistant Secretary on Petty Cash Account	15	4	5			
				351	0	2
Half-year's dividend on £7,500 Consols	109	4	5			
" " £5,700 New 3 per Cent. Stock	83	0	2			
Quarterly dividend on £7.500 Consols	54	12	3			
Bonus on conversion of ditto	18	15	0			
Quarterly dividend on £7,500 2¾ per Cent. Stock, late Consols	54	16	11			
Quarterly dividend on £5,700 2¾ per Cent. Stock, late New 3 per Cent.	41	13	8			
Quarterly dividend on £7,500 2¾ per Cent. Stock, late Consols	54	16	11			
Quarterly dividend on £5,700 2¾ per Cent. Stock, late New 3 per Cent.	41	13	8			
Four Quarterly Dividends on £750 Metropolitan 3 per Cent. Stock	21	18	6			
				480	11	6
Received on account of Subscriptions:						
Arrears	212	2	0			
256 Annual Contributions for 1888	537	12	0			
3 " " 1889	6	6	0			
29 Admission Fees	60	18	0			
20 First Contributions	30	9	0			
				847	7	0
13 Composition Fees				273	0	0
Sales of Publications:						
At Williams and Norgate's, 1887	7	19	0			
At Society's Rooms, 1888	31	5	6			
				39	4	6
Donation to Lee Fund. Mrs. Jackson Gwilt				5	0	0
				£1,996	3	2

Audited and found correct.

ROBERT BRYANT.
W. B. GIBBS.
THOMAS LEWIS.

Astronomical Society, from January 1 to December 31, 1888.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	225	0	0			
,, ,, for assistance in editing Society's Publications ...	50	0	0			
				275	0	0
Income Tax and House Duty				11	16	3
Fire Insurance				7	16	6
Printing	565	12	0			
Lithography and Engraving	46	13	6			
Computation of Ephemerides in *Monthly Notices* ...	50	0	0			
				662	5	6
Turnor and Horrox Funds: purchases for Library	17	4	10			
Binding Books in Library	18	18	9			
				36	3	7
House Expenses	35	19	1			
Wages	31	10	0			
Postage, &c.	54	6	11			
Carriage of Parcels	2	6	1			
Stationery and Office Expenses	5	12	5			
Expenses of Meetings	20	0	0			
Coals and Gas	56	1	6			
Installation of Electric Light in Society's Rooms	76	0	0			
Sundry Fittings and Repairs	16	9	5			
Whitewashing, &c.	22	2	0			
Rental of Wire for Time Signal	5	0	0			
Sundries	6	14	1			
				332	1	6
Mrs. Jackson Gwilt's Annuity				8	19	0
Lee Fund Grants				10	0	0
Bankers' Deductions on Cheques	0	2	7			
Cheque Book	0	8	4			
				0	10	11
Balances, December 31, 1888:—						
Balance at Bankers', as per pass book ...	345	19	8			
,, on Deposit Account	300	0	0			
,, in hand of Assistant Secretary on account of Turnor and Horrox Funds	0	14	10			
,, in hand of Assistant Secretary on Petty Cash Account	4	15	5			
				651	9	11
				£1,996	3	2

Assets and Present Property of the Society, January 1, 1889.

	£ s. d.	£ s. d.
Balances, December 31, 1888:—		
At Bankers', as per pass book...	345 19 8	
" on Deposit Account	300 0 0	
Balance in hand of Assistant Secretary on account of Turnor and Horrox Funds	0 14 10	
" in hand of Assistant Secretary on Petty Cash Account	4 15 5	
		651 9 11
Due on account of Subscriptions:		
13 Contributions of 3 years' standing ...	81 18 0	
27 " 2 " ...	113 8 0	
65 " 1 year's standing ...	136 10 0	
	331 16 0	
Less 3 Contributions paid in advance ...	6 6 0	
		325 10 0
Due from Messrs. Williams and Norgate for sales of Publications during 1888		36 7 1

*£7,500 2¾ per Cent. Stock, late Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

*£5,700 2¾ per Cent. Stock, late New 3 per Cents., including Mrs. Jackson Gwilt's gift (£300).

£750 Metropolitan 3 per Cent. Stock.

Astronomical and other Manuscripts, Books. Prints, Instruments, and Furniture.

Unsold Publications of the Society.

One Gold Medal.

* The interest that these investments will pay from next April has been reduced by the Chancellor of the Exchequer to 2¾ per cent., with a further reduction to 2½ per cent. in twelve years. A bonus of 5*s*. per 100*l* was paid on the conversion of Consols, as appears in the receipts. The payment of interest has been made quarterly, giving in the case of Consols one quarter's extra dividend in this year.

Report of the Auditors.

We have examined the Treasurer's accounts, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1888, including the balance at the bankers', and a sum of 300*l.* on deposit, amounted to 651*l.* 9*s.* 11*d.*

The funded property of the Society is the same as at the end of last year.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid upon the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) W. B. Gibbs,
Thomas Lewis,
Robert Bryant.

February 8, 1889.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXIX.	410	...
I. Part 2	42	...	XXX.	159	1
II. Part 1	55	...	XXXI.	143	...
II. Part 2	20	...	XXXII.	154	1
III. Part 1	66	1	XXXIII.	164	...
III. Part 2	85	1	XXXIV.	164	4
IV. Part 1	79	3	XXXV.	109	5
IV. Part 2	91	3	XXXVI.	198	8
V.	105	4	XXXVII. Part 1	339	8
VI.	124	3	XXXVII. Part 2	286	8
VII.	148	3	XXXVIII.	274	1
VIII.	127	3	XXXIX. Part 1	246	4
IX.	134	3	XXXIX. Part 2	250	3
X.	145	...	XL.	267	1
XI.	154	...	XLI.	414	1
XII.	159	...	XLII.	236	4
XIII.	163	...	XLIII.	240	1
XIV.	370	2	XLIV.	220	...
XV.	140	...	XLV.	251	1
XVI.	165	...	XLVI.	239	3
XVII.	147	1	XLVII. Part 1	3	...
XVIII.	146	...	XLVII. Part 2	19	...
XIX.	152	...	XLVII. Part 3	2	...
XX.	142	...	XLVII. Part 4	10	...
XXI. Part 1	314	...	XLVII. Part 5	10	...
XXI. Part 2	99	...	XLVII. Part 6	10	...
XXI. 1 & 2 (together)	61	...	XLVII.	219	2
XXII.	164	...	XLVIII. Part 1	264	3
XXIII.	150	...	XLVIII. Part 2	284	1
XXIV.	156	...	XLIX. Part 1	575	7
XXV.	166	...	Index to *Memoirs*	645	...
XXVI.	172	...			
XXVII.	422	...			
XXVIII.	382	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	65	...	XXVI.	10	...
II.	67	...	XXVII.	3	...
III.	...	...	XXVIII.	72	1
IV.	...	...	XXIX.	53	...
V.	...	...	XXX.	66	2
VI.	35	...	XXXI.	96	...
VII.	2	...	XXXII.	118	5
VIII.	138	2	XXXIII.	98	2
IX.	25	3	XXXIV.	77	2
X.	174	1	XXXV.	60	1
XI.	185	1	XXXVI.	32	1
XII.	11	2	XXXVII.	39	3
XIII.	157	3	XXXVIII.	97	2
XIV.	109	3	XXXIX.	108	1
XV.	127	2	XL.	113	3
XVI.	108	2	XLI.	113	5
XVII.	137	1	XLII.	122	1
XVIII.	166	...	XLIII.	122	1
XIX.	58	...	XLIV.	125	4
XX.	34	...	XLV.	126	3
XXI.	17	...	XLVI.	130	3
XXII.	33	...	XLVII.	127	6
XXIII.	19	...	XLVIII.	132	11
XXIV.	24	...	Index to *Monthly Notices*	567	4
XXV.	7	...			

Library Catalogue 608

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLVIII. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided

on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

No. 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.

„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.

„ 91. Astronomical time watchcase, by Professor Chevallier.

„ 92. 2-foot protractor, with two movable arms, and vernier.

„ 93. Beam compass, in box.

„ 94. 2-foot navigation scale.

„ 95. Stand for testing measures of length.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

„ 97. 12-cell Leclanché battery.

„ 98. 2 feet 6 inch navy telescope with object-glass $2\frac{1}{4}$ inches, by Cooke, with portable wooden tripod stand.

„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.

„ 100. 9-inch transit instrument, with level and iron stand.

„ 101. Small equatoreal sight instrument, by G. Adams, London.

„ 102. Sun-dial, by Troughton.

„ 103. Sun-dial, by Casella.

„ 104. Sun-dial.

„ 105. Box sextant, by Troughton and Simms.

„ 106. Prismatic compass, by Schmalcalder, London.

„ 107. Compass, by C. Earle, Melbourne.

„ 108. Prismatic compass, by Negretti and Zambra.

„ 109. Dipleidoscope, by E. Dent.

„ 110. Abney level, by Elliott.

„ 111. Pocket spectroscope, by Browning.

„ 112. Small brass astrolabe.

„ 113. Double sextant, by Jones.

„ 114. Two models, illustrating the effects of circular motions.

„ 115. A cometarium.

„ 116. A pair of 18-inch globes.

„ 117 } Two old sun-dials.
„ 118 }

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-in. portable refracting telescope, by Tulley, with tripod stand (bequeathed by the late Mr. W. H. Bartlett).

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. 30-in. transit instrument, with one stand, to Mr. C. Thwaites.
„ 28. (2) 6-inch theodolite and stand, to Mr. A. A. Common.
„ 29. (3) Equatoreal mounting, clock movement, and stand, to Mr. W. Peck.
„ 30. (4) 3¼-inch equatoreal and stand, to Mr. E. B. Powell.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 39. (13) Repeating circle, to Mr. J. N. Lockyer.
„ 42. (16) Reflecting circle and stand, to the Rev. H. P. Slade.
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 74. Registering spectroscope, to Mr. J. D. McClure.
„ 76. 5-prism direct-vision spectroscope, to Mr. E. W. Maunder.
„ 108. Prismatic compass, to the Rev. A. Freeman.
„ 123. 6-in. refractor, by Grubb, to the Rev. A. Freeman.

The Gold Medal.

The Council have awarded the Society's Gold Medal to M. Maurice Lœwy for his Equatorial Coudé, his method of determining the constant of aberration, and his other astronomical researches. The President will lay before the Society the grounds upon which the award has been founded.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows during the past year:—

Fellows:—Francis Barrow.
W. H. Bartlett.
Sir C. T. Bright.
J. Rand Capron.
William Cotterell.
Rev. P. A. Fothergill.
Commander J. Ll. Heane.
Rev. R. F. Heath.
Col. A. S. H. Lowe.
Ole Möller.
J. D. Perrins
R. A. Proctor.
J. O. N. Rutter.
James Wigglesworth.

Francis Barrow was born in 1821. He was the only son of the Rev. Francis Barrow, vicar of Cranbrook in Kent. He graduated at Oxford, where he took his B.A. degree in 1841, and his M.A. in 1844. He was called to the Bar at Lincoln's Inn in 1844, and commenced to practise as a special pleader. He went the Home Circuit and was frequently at Cranbrook, where he made the acquaintance of Mr. Dawes, who came to reside there in 1844. This friendship greatly developed his taste for astronomy, and he subsequently erected an observatory of his own at the rear of his house in Phillimore Gardens, Kensington. In 1850 he married Catherine Clara, a daughter of the late Admiral Thomas Dick. He was a Justice of the Peace for the county of Kent, and was appointed Recorder of Rochester in 1867, and in 1876 he was appointed a County Court Judge. He died on September 13, 1888, at his house in Phillimore Gardens.

Mr. Barrow was elected a Fellow of the Society 1870, Nov. 11, and held the office of treasurer from Feb. 1878 to Feb. 1884.

Charles Tilston Bright was born at Wanstead in 1832, and was the youngest son of Mr. Brailsford Bright, of Wanstead.

He was educated at Merchant Taylors' School, and showed special scientific aptitudes very early in life, his attention being particularly directed to chemistry and electricity.

In 1847, at the age of fifteen, he became acquainted with the late Sir William Fothergill Cooke, and was introduced into the service of the Electric Telegraph Company, at that time established to work the patents of Cooke and Wheatstone. From 1847 to 1850 he was connected with the Electric Company, the British Company, and finally with the Amalgamated British and Irish Magnetic Telegraph Company, of which his brother, Edward Bright, had been appointed manager. In 1852 he was appointed engineer to the Company, and at this time he was occupied in carrying out a most extensive scheme of underground wires between London, Manchester, Liverpool, and other places.

Perhaps the first work which brought Charles Bright into public notice was, at the age of nineteen, laying underground the Manchester telegraph lines under the streets of that vast city in one single night without disturbing the traffic.

Charles Bright's connection with the Magnetic Company continued as engineer, and then as consulting engineer, up to the year 1870, when the telegraphs were acquired by the State.

It was during this period that he undertook the great work with which his name is inseparably connected. To mention the Atlantic cable is at once to bring the name of Charles Tilston Bright before us. During the time that the underground system of wires was growing under his hands he was carrying out numerous experiments as to the effects of the transmission of signals through long distances. In his inaugural address in January 1887 to the Society of Telegraph Engineers he says: "Having a great length of underground gutta-percha-covered wire under my control as engineer of the Magnetic Company, I carried out a long series of experiments by having the wires connected up backwards and forwards between London and Manchester so as to form a continuous circuit of a length equal to that of a telegraph cable between Ireland and Newfoundland, or more than 2,000 miles. My method was to use a succession of opposite currents, which I had previously found to be successful with the magneto-electric currents used by that company. I could only try my experiments at night, or on Sundays, when the traffic on the line was small. I showed Professor Morse one night that signals could be sent at the rate of 210, 241, and in one experiment at the rate of 270 signals per minute through that continuous circuit of 2,000 miles of the company's underground wires between London and Manchester. The wires were joined backwards and forwards at Manchester and London, in each loop at both ends a galvanometer being inserted in the circuit to prove that the currents really passed through. By this the resistance, though not the retardation, of the line was largely increased."

The details of laying the Atlantic cable are matters of

history. Suffice it is to say that in carrying out this great work Sir Charles Bright showed himself a man of extraordinary energy and power, rapid in thinking and acting, and endowed with courage and perseverance under difficulties—qualities which enabled him to bring this never-to-be-forgotten undertaking to a successful issue. In recognition of these great services rendered by him to the country and to science, Charles Tilston Bright in the year 1858 received the honour of knighthood at the early age of 26 years.

Sir Charles Bright's subsequent career is closely connected with many great works of telegraph engineering in different parts of the world, which he carried out with the same thoroughness that uniformly distinguished him. It is almost superfluous to mention the numerous instruments and appliances he invented for the improvement of telegraphy, which are well known.

The works he accomplished bear evidence of his skilful handiwork, his intuitive knowledge, and unerring judgment, and as the great fabric of the modern telegraph system rises and spreads throughout the world, its foundations and superstructure bear evidence of the vital part played by him in their construction and formation.

Sir Charles Bright was a Fellow of several learned societies, and was a member of the Institution of Civil Engineers. In 1865 the council of that institution awarded him the Telford Gold Medal. In the same year he was returned to Parliament as member for Greenwich. In 1881 he was appointed one of the British Commissioners at the Paris International Exhibition, and received from the French Government the cross of the Legion of Honour. In 1886 he became President of the Society of Telegraph Engineers and Electricians.

In 1853 Sir Charles Bright married the daughter of the late Mr. John Taylor, of Kingston-upon-Hull, by whom he leaves issue. He was taken suddenly ill while on a visit to his brother, and died of heart disease May 3, 1888.* He was elected a Fellow of this Society 1860, December 14.

John Rand Capron was born in London, February 19, 1829. He was educated at the Grammar School, Guildford, and on completing his studies was articled to his uncle, Mr. John Rand, a solicitor in extensive practice in that town. After being admitted a solicitor, in 1850, Mr. Capron entered into partnership with his uncle, and subsequently succeeded to the business. He was soon appointed Borough Coroner and Clerk of the Peace, which latter appointment he held up to the time of his death.

In the midst of his many business cares and public engagements, Mr. Capron found leisure to gratify his enthusiasm for the study of natural phenomena, and it is as a scientific man of some distinction that his name will be best remembered. When

* Collated by permission from the *Electrical Review*.

at school he had a severe attack of typhoid fever, and during his convalescence a compound microscope was lent to him. This opened out a new world of wonder and beauty, and was the means of firing his ambition to examine some of the fascinating mysteries of creation. He took a special interest in studying the Earth's surface, making considerable progress in geology, and forming a collection of fossils and minerals of great interest and variety. But later on he turned his attention to spectroscopy and meteorological phenomena, and became a devoted student of astronomy.

In 1877 Mr. Capron published an important work on "Photographed Spectra," in which he gave, in a very easy and convenient form for reference, 136 photographs of metallic, gaseous, and other spectra, accompanied by critical explanations. For obtaining the spectra of the metals he employed a direct-vision prism of an inch aperture, with collimator and camera, and with this spectroscope he obtained photographs of the spectra of some forty metals, extending from about *b* to H. For most of these metals two photographs were obtained—one taken with the induction spark, and the other with the electric arc from a battery of 40 pint Grove cells. For the spectra of gases, three different spectroscopes were employed, one of these having two simple quartz prisms of 60°, and the others each a direct-vision prism of large size. The value of this work was fully recognised at the time, as it brought together so many spectra simultaneously before the eye, thus giving a far greater insight into their physical characteristics than could so readily be obtained by a study of the individual spectra with the spectroscope one after the other.

In 1879 Mr. Capron published a popular treatise on "Auroræ and their Spectra." In this work he presented a very complete history of early and recent observations of auroral phenomena, in which he carefully records the general appearance and special characters of auroræ; their geographical distribution; colours, height, and noises attributed to them; phosphorescence, polarisation of their light, &c. The most valuable part of the work is that devoted to an investigation of the spectra of auroræ. The subject is very carefully and exhaustively discussed, and the author's long series of laboratory experiments to elucidate and explain some of the obscure phenomena of auroræ will always be of value in any consideration of the subject. Mr. Capron thus expressed the conclusion at which he arrived from his researches: "As the general result of spectrum work on the aurora up to the present time, we seem to have quite failed in finding any spectrum which, as to position, intensity, and general character of lines, well coincides with that of the aurora. Indeed we may say we do not find any spectrum so nearly allied to portions even of the aurora-spectrum as to lead us to conclude that we have discovered the true nature of one spectrum of the aurora, supposing it to comprise, as some consider, two or more."

In an interesting pamphlet published in 1882, Mr. Capron called particular attention to the subject of the "Rainband," and the importance of observing it as indicative of the presence or otherwise of an excess of moisture in the atmosphere. Among his other scientific papers may be mentioned one on the remarkable auroral beam of November 17, 1882, published in the *Philosophical Magazine*, and the following communications published in the *Monthly Notices*: "Report of Examination of Sun's Disk at Guildford, March 21, 22, 23, 1877, for Suspected Planet *Vulcan*"; "The Partial Eclipse of the Sun, December 31, 1880"; "The Lunar Eclipse, 1881, December 5"; "The *Andromeda* Meteors."

Mr. Capron was a man of the most beneficent and philanthropic character, and took much interest in all the social institutions of his neighbourhood. He subscribed to a large number of charities, and was ever ready, though in the most unostentatious manner, to afford aid and succour to those in poverty and distress.

He had been in failing health for some time past, but his illness took a more serious turn in October, and he passed away on November 12, 1888, at the age of 59 years.

Mr. Rand Capron was elected a Fellow of this Society 1877, March 9, and for five years, from 1883 to 1887, he was a member of the Council.

William Cotterell was one of those few men—whose number, however, may be greater than it seems—who combine the unremitting pursuit of science with the regular occupations of business. The love of physical science, and especially of astronomy, was inbred in him. He inherited it from his grandfather, who, though purely an amateur, made his own telescopes, and acquired instruction by means that would seem meagre in view of the facilities that are now within the reach of everyone. Mr. Cotterell's tastes were thus pronounced from his boyhood. As a youth he was accustomed to take observations of the heavens, which he recorded for himself, making his own star-maps, and diligently working out problems and calculations by methods of his own. Born at Walsall, in Staffordshire, on April 13, 1827, he spent his whole life there, except for a few years' residence in London as a young man. His life was singularly free from incident, except those unobserved incidents which the student is conscious of, and which he remembers as signs of progress or attainment. Though a good citizen, he took no part in public life, otherwise than as being an active member of the Midland Institute at Birmingham, and of the Dudley and Midland Geological and Scientific Society. In connection with those institutions, and more widely—indeed throughout the Midland counties—he was recognised as an authority on the two special subjects to which he had given most attention—namely, astronomy and geology, though his knowledge of the science of

chemistry was also considerable. Loving science wholly for its own sake, he never sought to give publicity to his labours, but they were nevertheless constant. A day seldom passed without some time being given to one or other of the studies that chiefly occupied his thoughts. He left two works in manuscript, which he could not be persuaded to publish. One was a series of dialogues on astronomy; the other he proposed to call "Elements of Physics." Mr. Cotterell died October 23, 1888. He had suffered for some years, at intervals, from bronchitis, and it was an attack of that malady that caused his death. He had at the time made all the necessary arrangements for retiring from business, and had hoped for some years of leisure, which he purposed to devote to his favourite studies, but this pleasant anticipation he was not permitted to realise.

He was elected a Fellow of this Society 1867, December 13.

Percival Alfred Fothergill, late Chaplain and Naval Instructor in the Royal Navy, and Domestic Chaplain to the Earl of Limerick, was the second son of the late Captain Henry Fothergill, 67th Regiment, and was born on July 26, 1830. He was educated at Trinity College, Dublin, where he graduated B.A. In June 1854 he entered the Royal Navy as Naval Instructor and was appointed to H.M.S. *Termagant* (Captain the Hon. Keith Stewart), which formed one of the Baltic squadron under the command of Sir Charles Napier.

Mr. Fothergill was present at the taking of Bomarsund in 1854, being one of the first Englishmen who entered that fort, and he received the Baltic Medal. He subsequently followed Captain Keith Stewart to H.M.S. *Nankin*, and served in China, where he received a medal with two clasps for services at Fatshan and Canton. In 1858 he received a further medal for services in India. For some time he was employed on surveying duty on the coast of Tartary.

In 1859 Mr. Fothergill took Holy Orders, and was subsequently appointed Rector of South Heighton with Tarring Neville, in Sussex. In 1866 he became Vicar of Watford, Northamptonshire, and in 1871 was appointed Rector of South Fambridge, Essex, which living he held to the day of his death, on August 24, 1888.

In 1863 he married the daughter of the late Captain Laugharne, of the Royal Hospital, Greenwich, Senior Captain of the Royal Navy, by whom he leaves issue two sons and three daughters.

Mr. Fothergill was the inventor of "Fothergill's Self-Feathering Screw," which was exhibited at the Exhibition of 1870. He was the author of "Evidence against the Working of the Law in Cases of Sequestration and Dilapidations," and one or two other works.

He was elected a Fellow of this Society 1859, December 9.

ARTHUR SWANN HOWARD LOWE was the youngest son of the late Alfred Joseph Lowe, J.P. for Nottinghamshire, and was born on December 4, 1826, at Highfield House, in the parish of Lenton, near Nottingham. He received his early education at Mr. Fletcher's school in Nottingham, and with private tutors at home.

In 1852 he entered the Nottinghamshire Militia, and eventually became colonel of that regiment, which he commanded up to the summer of 1887, when failing health compelled him to resign. During this long period of service he took a very active interest in everything that concerned the welfare and satisfactory condition of his regiment.

Colonel Lowe was greatly interested in all scientific pursuits, taking regular meteorological observations and watching astronomical phenomena with much zeal. He rendered material assistance to his brother, Mr. E. J. Lowe, in the preparation of a work on "The Climate of Nottingham." He was an excellent draughtsman, and undertook many illustrations of birds and their eggs. All the drawings of freshwater Mollusca, published in "The Conchology of Nottingham," were made by him.

Colonel Lowe was for many years a Life Member of the British Association, and also a Fellow of the Royal Meteorological Society. He was a magistrate for the county of Essex, and resided at Gosfield Hall, Halstead, where his death took place on August 4, 1888, after some months' illness.

He was elected a Fellow of this Society 1857, January 9.

OLE PETER MÖLLER was born in Denmark on July 22, 1831. He came to England as a youth, and was for more than thirty years a partner in the eminent firm of Galbraith, Pembroke & Co., of Austin Friars. He took a prominent part in all matters relating to sailors, more especially to Scandinavians. He was much interested in the building of the Norwegian Sailors' Church at Rotherhithe. Mr. Möller was also a Director of the Society for the Relief of Foreigners in Distress. In recognition of his services to the Scandinavian section of the Exhibition of 1862, and his ever-ready assistance in all matters relating to Sweden and Norway, H.M. King Oscar created him a Knight of the Order of St. Olaf. Though a lover of science, more especially of astronomy, Mr. Mölier did not undertake any active scientific labour.

He was elected a Fellow of this Society 1886, February 12.

JAMES DYSON PERRINS was born on November 27, 1823. As a young man he devoted himself to the study of chemistry, and published some researches on the organic base Berberine in the *Journal of the Chemical Society* and the *Annales de Chimie.* Mr. Perrins was early connected with the well-known firm of Messrs. Lea & Perrins at Worcester, with whom he remained an active partner up to the time of his decease. In his time he served in

many capacities in Worcester and the county. In 1860 he was returned to the Council of Worcester; in 1863 he was elected Sheriff, and in the following year became Mayor. Subsequently he was appointed Alderman. In the year 1871 he qualified as a Magistrate for the city, and in 1875 as a Magistrate for the county. In 1874 he was appointed a Severn Commissioner, and in 1885–86 he was elected to fill the position of High Sheriff of the county, a distinction which was evidence of the regard in which he was universally held.

Mr. Perrins took considerable interest in the advancement of the educational institutions in Worcester. He contributed in the most liberal manner to the Victoria Institute, the Public Library, the North Malvern School, and many charitable and useful institutions. The great fortune which fell to his lot was regarded by him as a possession involving commensurate responsibilities, and he was always a generous friend to any movement which expressed the educational and intelligent aspirations of the time. He was a connoisseur in art, and formed a valuable collection of pictures. He was much interested in literature and science, and was well read on many subjects. To this Society he presented a valuable 6-prism automatic spectroscope.

The death of Mr. Perrins, which took place February 26, 1887, leaves a considerable blank in the public and social life of the county of Worcester.

He was elected a Fellow of this Society 1870, May 13.

Richard Anthony Proctor was born in Cheyne Row, Chelsea, on March 23, 1837. He was the youngest of four children, two sons and two daughters, and was rather a delicate child. His mother seems to have been a clever woman. She kept him at home as long as possible, attending to his education herself. His boyish contemporaries remember him as a great reader, devouring books of a more advanced type than boys usually care for. His father, who was a solicitor with literary tastes, died when his little son was thirteen years old.

During later boyhood, Richard Proctor's health improved, and he was sent first to King's College, London, and then to St. John's College, Cambridge, where he obtained a scholarship. While an undergraduate his health still further improved, and he became decidedly athletic. He was captain of the "Lady Somerset," a Johnian Boating Club, and brought his boat up several places on the river.

During his second year at Cambridge he lost his mother, to whom he was devotedly attached; and shortly afterwards, while travelling with his sister, he fell in love with a young Irish lady, to whom he was privately married while at college. He came out in the Honours list of 1860 as twenty-third wrangler, a degree which greatly disappointed his friends, many of whom had already recognised his remarkable talent. Feeling unable to fulfil his mother's wish, and enter the Church, he commenced

to look about him for a profession. For a little time he hesitated with regard to the law, and ate dinners at the Temple; but ultimately he decided to devote himself to Astronomy. He lived for short periods first in Ayr, then in Edinburgh, then near Dublin, and afterwards in Devonport.

Mr. Proctor's first literary venture was an article on "Double Stars," which he sent in 1865, without introduction of any kind, to the editor of the *Cornhill Magazine*. He was greatly pleased to find it accepted, and he afterwards used to tell how he was on the point of despatching a letter of warm thanks to the editor for two copies of the magazine containing the article which had been sent him, when a letter arrived enclosing a cheque in payment. His first book was on *Saturn and its System*; it was published in 1865, at his own expense, and occupied him four years in preparation. When it was published it was very favourably received by astronomers, who recognised that a new writer of exceptional ability had appeared. Geometrical conceptions were expounded with great clearness, and astronomical and historical details were explained with an ease and enthusiasm which attracted the reader. But, though the book was well received by the reviewers, the public did not buy it, and he found, to his great disappointment, that its publication was a source of loss instead of profit. This came upon him at a time of great monetary anxiety, for he was a considerable shareholder in a New Zealand bank which failed during the commercial panic of 1866, entirely absorbing his capital. His family was increasing in number, and the grave question pressed upon him whether it was not his duty to forsake Astronomy and devote himself to teaching, or seek an official appointment. He preferred the independent position of an author, and had a great idea of the importance of the calling. By one of those strange coincidences which occasionally occur, he had received from Dr. Henry Lawson, the editor of the *Popular Science Review*, only a day or two before the news of the bank failure reached him, a request to write a couple of articles on "The Telescope," and an unfinished letter was lying on his desk at the time that the news arrived declining the task. The next morning he set to work at the first of the required articles, and, "from that day onward for five years," he says in some meagre notes for an autobiography which he has left, "I did not take one day's holiday from the work which I found essential for my family's maintenance."

It frequently seemed to him that he must give up all idea of continuing scientific work. He says: "I would willingly have turned to stone-breaking on the roads, or any other form of hard and honest but unscientific labour if a modest competence in any such direction had been offered me." Editors of magazines and journals are not always versed in scientific matters, and his articles were continually sent back to him. Even Anthony Trollope wrote to him, on receiving an article on "The Gulf

Stream," that it seemed interesting, but he must ask for some evidence to show that the author was competent to deal with a subject of the kind in a scientific way. Fortunately, Mr. Proctor was able to satisfy him, and the article appeared in due course in the *St. Paul's Magazine.* The publishers were equally shy of his proposed books and star atlases. At the beginning of the struggle he offered to Messrs. Longman, with whom he had published his *Saturn*, his *Handbook of the Stars*, but they would not take it. Then he tried Messrs. Macmillan, but they would not venture. So with the help of a friend 500 copies were printed, which sold and paid expenses. With similar help he brought out his *Constellation Seasons*, drawn by himself in transfer for the stone, and his *Sun Views of the Earth*, produced in the same inexpensive way. Both books paid their expenses and a few pounds over, but no new editions were prepared. At last Messrs. Hardwick engaged him to write a small book called *Half-Hours with the Telescope* for 25*l.* It sold well, and they bought the copyright of him for 25*l.* on each of the first two thousand copies. The book is now in its twentieth edition.

During this period he advertised for pupils in mathematics, and for a time took the position of mathematical teacher with a military coach at Woolwich for young men entering at Woolwich and Sandhurst; but the work was very distasteful to him. Slowly he obtained a footing first with one magazine and then with another. He became a regular contributor of *The Intellectual Observer* (afterwards *The Student*), then of *Chambers' Journal* and the *Popular Science Review.* Book after book was rapidly completed, and was accepted on more or less beneficial terms by publishers.

In 1872 he was elected one of the honorary secretaries of the Royal Astronomical Society, which post he held till November, 1873, when he retired in order to go to America on a lecturing tour. During this period he contributed many important papers to the *Monthly Notices* on "Star Distribution," "The Construction of the Milky Way," "The Distribution of Nebulæ and Star Clusters," and on "The Proper Motions of Stars," etc. These papers, which are illustrated by excellent maps, completely disposed of the artificial theories which had previously been in vogue with respect to the construction of the stellar universe. No doubt some advances had already been made on Sir William Herschel's "flat grindstone" hypothesis with respect to the form of the Milky Way, but Mr. Proctor's papers were the first which graphically showed the results which had been arrived at, and they materially extended the generalisations which may now be said to be universally accepted.

He also communicated to the Society a series of papers on Transits of Venus, in which he examined into the conditions of observation for the Transits of 1874 and 1882 with great thoroughness and at much detail. These papers, like those on

stellar distribution, were very fully illustrated by maps and diagrams.

Amongst other matters with which Mr. Proctor's name will always be associated in the history of Astronomy may be mentioned the accurate determination of the rotation period of the planet Mars. His result, obtained from a careful comparison of drawings dating from 1666 to the present day, is $24^h\ 37^m\ 22^s{\cdot}735$, with a probable error of $0^s{\cdot}005$.

Another piece of original research with which Mr. Proctor's name will probably remain associated is connected with the resisting medium in the lower coronal region, which he definitely showed offers a very appreciable resistance to the upward flight of the matter of solar prominences, when compared with the velocity of a projectile thrown upward in free space under the influence of solar gravity. The paper in which this is shown is contained in the *Monthly Notices*, vol. xxxi. p. 184. Mr. Proctor was an adept in all that refers to methods of projection and map-drawing. One of his greatest undertakings was the charting of the 324,000 stars contained in Argelander's great *Catalogue*, showing the relation of stars down to the eleventh magnitude, with the Milky Way and its subsidiary branches. His energy was almost unbounded. He wrote fifty-seven books, a list of the more important of which is given below. He played with great expression on the piano, and found time for musical practice as well as for chess and whist, both of which games he played extremely well. He wrote on "Luck and Chance," on the "Geometry of Cycloids," on "Mental Phenomena," on "Athletics" and many other subjects.

Mr. Proctor married twice, his first wife having died in 1879, leaving six children. He married again in America, on his return from a lecturing tour in the Australian Colonies, a widow with two young children. Some little time after this marriage he settled in America, and was returning to England from Florida when he was taken ill in New York. The doctors, believing him to be ill of yellow fever, ordered him to be removed from the hotel on a windy and rainy night, and he died within twelve hours of his removal on September 12, 1888.

Mr. Proctor's last and most important work, *Old and New Astronomy*, on which he had been occupied for some years, and to which he had given his best energies, was not finished at his death; but he has left a considerable collection of material for the remaining chapters, and the book will be completed by a friend.

It may certainly be said of Mr. Proctor that he has succeeded in interesting a larger public in the science of astronomy than any other man. His books have been read and his lectures have been listened to not only in England and America, but in most of the English Colonies; and the wide interest he has stirred up in astronomical subjects will no doubt have far-reaching results and bear important fruit.

He was elected a Fellow of this Society 1866, June 8.

A. C. R.

The following are some of the more important works published by Mr. Proctor:—*Saturn and its System* (1865), *Handbook of the Stars* (1866), *The Constellation Seasons* (1867), *Half-Hours with the Telescope* (1868), *Other Worlds than Ours* (1870), *Star Atlas* (1870), *Light Science for Leisure Hours* (1871), *The Sun* (1871), *The Orbs Around Us* (1872), *Essays on Astronomy* (1872), *The Expanse of Heaven* (1873), *The Moon* (1873), *The Borderland of Science* (1873), *The Universe and the Coming Transits* (1874), *The Transit of Venus* (1874), *Our Place among Infinities* (1875), *Myths and Marvels of Astronomy* (1877), *The Universe of Stars* (1878), *Treatise on the Cycloid* (1878), *Flowers of the Sky* (1879), *The Poetry of Astronomy* (1880), *Mysteries of Time and Space* (1883), *The Universe of Suns* (1884), *The Seasons* (1885), *Other Suns than Ours* (1887), *Old and New Astronomy* (1888).

John Obadiah Newell Rutter, who died at Black Rock, Brighton, July 27, 1888, was born in the Isle of Grain, Kent, April 19, 1799. Mr. Rutter was eminently a self-made man. At a very early age his father left England to try his fortunes in the then new colony of New South Wales, where he died in 1806, leaving his son to the care of his uncles and aunts in England, who trained and educated him in such fashion as the opening years of this century afforded. However, in after years he always spoke with gratitude of the kindness shown to him, especially of the motherly care he received at the hands of his aunt Cecilia, who became the wife of the late Dr. Lee, of Hartwell. Learning appears to have come natural to young Rutter, and even at the age of eight years he loved reading, and as years went on he eagerly devoured everything in the way of books brought within his reach. Apprenticeship to a trade followed as a matter of course to one in his position.

As a young man he took to scientific pursuits. He soon acquired a good knowledge of chemistry, and lectured thereon on several occasions. Before 1835 we find him greatly interested in the manufacture of coal-gas, and in the autumn of that year he removed to Brighton to take charge of the Brighton Gas Light and Coke Company. This proved to be the work of his life. From that date until 1882, a period of forty-seven years, his best thoughts were devoted to the service of that company. His own words, in which he desired to record the work of his life, are:—"During fifty years I was engaged, in addition to my other occupations, in promoting the domestic uses of gas. More than half a million of my publications on that subject have been sold."

In addition to chemistry Mr. Rutter devoted himself closely to electricity, upon which subject he gave popular lectures. In 1850 he patented an electric indicator, or fire and thief alarm, and a working model of its adaptation to a house was exhibited in the 1851 Exhibition. In 1854 he published a work on

Human Electricity. For forty years, with but slight intermission, he had one of Alexander Bain's electric clocks at work. As a meteorologist he was most painstaking and diligent in taking observations. As a boy he had knocked about a good deal off the Hampshire coast, and the knowledge then acquired of tides, wind, currents, and nautical matters never forsook him. His fifty-three years' residence in one house at Black Rock gave him a very accurate knowledge of the meteorology of Brighton.

This is not the place in which to record his inner life. We may only say that he was a most charitable man, and as years increased the love of giving increased. He spent a busy, practical, and useful life, with only a brief period of rest. He laid down to die after he had commenced his 90th year.

He was elected a Fellow of this Society, 1835, January 9.

James Wigglesworth was born in 1825, and during the whole of a very busy life had but one recreation, viz. the study of Astronomy. He was an exceedingly careful observer, and had it not been that his health gave way almost immediately after the erection of his large observatory at Scarborough, much good work would have been done there with the assistance of Mr. Lohse, who was engaged by him as observer. Mr. Wigglesworth was on very intimate terms with the late Thomas Cooke, and in 1853 purchased the first 6-inch refractor made by him. This instrument was in use by Mr. Wigglesworth for thirty years. In 1879 Mr. Wigglesworth purchased the Buckingham Works of Messrs. Cooke at York, and that old firm of eminent opticians is now carried on by his son in connection with Messrs. F. and T. Cooke. Mr. Wigglesworth was elected a Fellow of this Society 1885, January 9.

(*Omitted Obituary* for 1883.)

Karl Knorre, the son of Christoph Knorre, Extraordinary Professor of Astronomy in the University of Dorpat, was born in that town $\frac{28 \text{ March}}{9 \text{ April}}$, 1801. In his tenth year he lost his father, whose widow, being left with three children, and in poor circumstances, then went to live with her brother, Karl Senff, who was also a professor in the Dorpat University.

Knorre had from childhood shown great mathematical talent, which rapidly developed under the encouraging instruction of his father into a striking inclination for the exact sciences. This gave him the power even during the lifetime of his father (while yet only eight years old) to perform some minor services in the teaching of mathematics, and after his father's death the boy assisted his mother with the small income derived from the lessons which he gave.

In 1812 Knorre entered the Dorpat Gymnasium, and five years later proceeded to the University, where, in accordance with the wish of his uncle, he commenced the study of theology.

Feeling no inclination for this, however, he soon discontinued it, and gave himself with zeal and pleasure to the private study of mathematics and astronomy, which sciences he had never studied at the University. During the short time that he attended the theological faculty he devoted his nights to astronomical observations in the Observatory. This private study, without any other help than that of his books, says much for his extraordinary talent. At this time the survey of Lirland was undertaken by W. Struve, who selected Knorre as his assistant, thereby giving a new impetus to his studies.

In 1812, on the recommendation of Struve, and by the desire of Admiral Greig, Knorre was appointed Professor of Practical Astronomy at the School of Navigation in Nikolajew. This appointment opened the fairest prospects for the future, as it gave him the direction of an observatory, which was to be built under his superintendence.

The Black Sea fleet was then under the command of Admiral Greig, and to this intelligent and generous man many useful institutions owe their origin, among which the Observatory of Nikolajew takes an honourable place. The tasks set before it were: (1) To satisfy the demands and needs of the marine; (2) to form a centre for the hydrographic operations about to be commenced; (3) to engage in purely scientific work. Knorre devoted himself with zeal and ability to perform these duties allotted to his observatory, and won for it by his labours a worthy position among the observatories of Europe. In 1824, four years after Knorre's entrance upon his duties, Admiral Greig procured for him the means for a two years' scientific journey abroad. Knorre visited the principal observatories and manufactories of astronomical instruments in Germany, England, and France, and became personally acquainted with the heroes of his science. In the summer of 1827 he arrived at Munich at the same time as Bessel, who entrusted to him a portion of the computations for his "Tabulæ Regiomontanæ," which was published at Königsberg in 1830.

He returned to Nikolajew in the autumn of 1827, and entered on his duties in his new, almost completed observatory, which he continued to direct for fifty-one years with uninterrupted devotion and zeal. He was compelled to do everything himself, as he never had an assistant or any other help in his work. At the same time he gave lectures on practical astronomy at the School of Navigation until 1865, when, in consequence of the non-existence of the Black Sea fleet, the institution was closed. Thus all the navigating officers were his former pupils, and not a few of them became able specialists under his tuition. Under his direction and with his co-operation were carried on during thirty years the detailed surveys of the coasts of the Black Sea and the Seas of Azof and Marmora, as well as the straits connecting them and the rivers opening into them. Knorre commenced these surveys personally in the summer of

1822. Later on he gave advice both as to the observations and the carrying out of the work; he determined the formulæ for the computations of the observations, submitted them to strict proof, and calculated many himself. His hydrographic work, however, was not confined to these labours. Admiral Greig, who knew how to value and reward his many-sided ability and mathematical knowledge, employed him to solve and work out various problems relating to shipbuilding, which, though by no means belonging to his branch of study, his comprehensive knowledge enabled him completely to master.

The following is a list of Knorre's printed works:—

1. Der Ort des Polarsterns für jeden Tag der Jahre 1823–30. (Nikolajew, 1824.)
2. Der Ort des Sterns δ *Ursæ minoris* für jeden Tag der Jahre 1823–30. (Nikolajew, 1824.)
3. Sheet 5 of the *Berliner Akademische Sternkarten*, with the Catalogue of Stars. (Berlin, 1835.)

(*In Russian.*)

4. Solution of Triangles. (Nikolajew, 1832.) [In this work plane trigonometry is treated as a special case of spherical. As the sides of a spherical triangle become infinitely small, the formulæ are transformed into those of plane triangles.]
5. Researches on the "Progressika" (Nikolajew 1838). [The "Progressika" is the curve $(n-1)xy^2+ay^2=b^2nx$. It is used in calculations connected with shipbuilding.]
6. Instructions for the Determination of the Altitude of the Pole, Clock Correction, and Instrumental Errors by Gauss's Method. (Nikolajew, 1832.)
7. On the Star Maps, the preparation of which has been undertaken by the Berlin Academy. (Nikolajew, 1836.)
8. Treatise on the work of Prof. Sawitsch, "Anwendung der praktischen Astronomie zu geographischer Ortsbestimmung." (St. Petersburg, 1845.) [For this work Knorre received the Gold Medal of the St. Petersburg Academy.]
9. Exposition of Bessel's Method of Clearing Lunar Distances. (Nikolajew, 1837.)
10. Determination of the Error of Collimation of the Mirror in Magnetic Theodolites. (Nikolajew, 1869.)
11. Lectures on Practical Astronomy, given in the School of Navigation of the Black Sea Fleet.

Besides these works, he was the author of many contributions to Schumacher's *Astronomische Nachrichten*, and Demidoff's "Voyage dans la Russie Méridionale et la Crimée"; also of

many years' magnetical and meteorological observations in Kupper's "Sammlungen," and of many smaller papers and translations. He furnished yearly, without remuneration, the astronomical part of the almanacs published in Odessa and Tiflis, besides lesser contributions to these works. There also deserves to be mentioned his improvement in sextants, consisting in the placing of a level upon the alhidade. By this arrangement the identification of a star observed in a mercurial horizon with the image reflected from the mirror is considerably facilitated (*Astron. Nachr.*, Band 7, p. 262).

The most important work of Knorre's was sheet 5 of the *Berliner Akademische Sternkarten.* It was chiefly the accuracy and completeness of this sheet that inspired a zealous lover of astronomy, the late Secretary Hencke, of Driesen, with the idea that the continued comparison of this map with the heavens must lead to the discovery of new planets. Hencke's perseverance was rewarded on December 8, 1845, by the discovery of *Astræa.* This brilliant success made a great impression on the scientific world, and at once engaged many young astronomers in similar researches. On July 1, 1847, Hencke succeeded in discovering another planet, *Hebe,* and this was followed, on August 13 of the same year, by the discovery of *Iris* by Mr. Hind. Since then so many minor planets have been found, that the number of discoveries yet to be made can no longer be reckoned. When astronomical history records these discoveries it will be acknowledged that Knorre's map gave the first impulse to this enrichment of our knowledge of the Solar System, so far surpassing all expectations.

Thus he lived and worked during half a century, in a great measure cut off from cultivated scientific society, and depending almost entirely on himself and his books. He often felt this keenly, although otherwise contented with his respected and independent position.

After the conclusion of the Crimean war Nikolajew, which, on account of its admiralty and observatory, as well as being the seat of administration, had the charge of attending to the wants of the Black Sea fleet, lost its special function. The observatory also obviously lost the object of its existence, and its high position was reduced by this sudden change. The blow which followed the Treaty of Paris in 1856 seemed the more crushing, in that Greig's creations in Nikolajew had been so promising and important for the future, and so significant in their successes. Knorre was filled with sorrow and anxiety; his hopes for the future of his observatory were destroyed; yet he was by no means disheartened, and did not relax his energies. With continued ardour and zeal he carried on his usual duties, besides his scientific labours, though in the latter he was greatly hindered by the unfavourable circumstances resulting from the catastrophe already mentioned. The observatory, which had been an attribute of the marine, suffered the loss of its position

and significance, and sank into the background. It was now little regarded, and was deprived of the means for performing various tasks, and particularly of the means for purchasing new astronomical instruments which were necessary to Knorre for his observations and studies. As a scientific institution it was only the European fame and highly-esteemed personality of its director that preserved for the observatory its honourable position and continued existence. In order to duly appreciate its achievements these unfavourable circumstances must always be taken into account. In this manner, and in the midst of these discouraging surroundings, Knorre performed his duties in the observatory which had become so dear to him for fifteen years longer, till the summer of 1871. A man of seventy, he now longed for repose, and in August 1871 he resigned his position, retiring from the service with the rank of a "Geheimrath." In September he left with his family for Berlin, where he spent the evening of his life in rest and retirement. After a period of twelve years, which he passed in happiness and contentment in the midst of his family, he passed peacefully away on September 10, 1883, in the 83rd year of his life.

From his great talents and wide knowledge, as well in the exact as in other sciences, Knorre was an authority not only in naval circles and in those of his scientific friends, but also among the intelligent inhabitants of Nikolajew, who highly valued his opinion and advice, which were given with kindliness and courtesy to all who came to him for instruction and information. Through the nobility of his character and his generous views he won universal respect and sympathy from all who knew him.

Professor Knorre was elected an Associate of this Society 1848, May 12.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

At the beginning of the year 1888 the Y's of the transit-circle were taken out, thoroughly cleaned, and readjusted so as to correct the large level and azimuth errors which had gradually developed, a sheet of tinfoil being placed under the western Y. From a recent discussion of these errors (*Monthly Notices*, 1887, vol. xlvii., p. 325) it appears that each is subject to changes in course of years: the level error has had in recent years a tendency to become negative; that is, the eastern pivot is now rising relatively to the western, though in the years 1851–1870 the contrary tendency was noticed. For the year 1887 the mean value was distinctly negative, the extreme values being $-10''\cdot2$ on June 15 and $-1''\cdot2$ on October 12. By the operations in 1888, January, this error was advisedly over-corrected, so that the mean level error is now positive. The extreme values in 1888 were $+7''\cdot0$ on January 17 and $-2''\cdot0$ on August 10.

The azimuth has recently shown a change in the positive direction; that is, the eastern pivot has been moving relatively north, though in the period 1851–1870 it was comparatively steady. The extreme values in 1887 being $+15''\cdot9$ on August 31 and $+2''\cdot8$ on April 14, this error was also over-corrected, so that the extreme values in 1888 were $-8''\cdot2$ on April 7 and $+3''\cdot3$ on September 27 and October 26. The mean level error is thus $+2''\cdot5$, and the mean azimuth error $-2''\cdot5$.

The regular meridian work has been carried on as before throughout the year 1888. The number of transits observed was 5,186, and of zenith distances 4,979; the total number of stars observed in the year being 1,816. Of stars for special purposes, 106 observations have been made in all of the 28 comparison stars used by Dr. Gill for the opposition of *Iris*, the planet herself having been observed with the transit-circle on eighteen nights. Stars used in the determination of the longi-

tude Paris-Greenwich have also been put on the working list, and 45 stars with remarkable spectra.

The mean error in R.A. of Hansen's lunar tables with Professor Newcomb's corrections, as deduced from 79 observations with the transit-circle in 1888, is $+0^{s}\cdot079$, showing a slight increase on the mean for 1887, $+0^{s}\cdot068$, which was itself an advance on the steady value of $+0^{s}\cdot03$ found from observations in the years 1883–1886. The comparatively small number of observations in 1888 is an indication of the bad weather in the summer, only three meridian observations of the Moon having been made in June, and only five in July, though the corresponding numbers for 1887 were thirteen and fourteen respectively.

Observations of the horizontal flexure of the transit-circle by means of the collimators on 1888, February 29, April 10, April 12, and 1889, January 3, gave $-0''\cdot11$, $+0''\cdot28$, $+0''\cdot13$, and $+0''\cdot08$; agreeing with the results of recent years in indicating that the horizontal flexure is sensibly zero.

The apparent correction to the nadir observation deduced from reflection observations of stars in 1888 is $-0''\cdot118$, the numerically largest value for any month being $-0''\cdot43$ for the month of May (20 nights). No correction for this discordance has been applied.

In 1879 observations were made in the months of May and June on the distribution of temperature in the transit-circle room, thermometers being placed at selected points; but the investigation was not carried further when it became evident that there was no serious anomaly in the gradual diminution of temperature outwards from the instrument. It has recently seemed desirable to make a more complete investigation, and three thermometers mounted in the middle and at the north and south angles of the horizontal shutter opening have been regularly read in 1888, with the three thermometers ordinarily in use. So far, the observations seem to show that the temperature at night falls off more rapidly towards the south than towards the north, and that the surfaces of equal temperature tend to follow the angular shape of the room. The observations will be continued in 1889.

A proposal having been made for the construction of a new line of railway in a tunnel across Blackheath (in extension of the authorised Bexley Heath Railway), some experiments were made in March and April on the disturbance caused by existing railways. One observer at the transit-circle noted the times of all disturbances of the image of the wires as seen by reflection from the surface of mercury, while other observers travelling on the trains or taking up positions at railway stations noted quite independently the positions and movements of all trains as far as was possible. On comparing the two lists of observations it became apparent that tremors were caused by trains up to a distance of one mile at least, the disturbance becoming so great at shorter

distances as to make the reflected image invisible, and being increased by passage of the trains through tunnels.

Owing to pressure of other work the personal equation machine has not been used in the past year.

The current reductions have been kept up to date by rather special efforts, in view of the heavy work requisite for the forthcoming "Ten-Year Catalogue."

The straightforward reductions for the "Ten-Year Catalogue" are practically completed; there remains, however, the examination of discordances and the correction of errors. Besides the accidental errors a list has been prepared of cases where the thermometer was not read sufficiently near the observation of a star, and where a correction to the adopted reading may be advantageously inferred from the photographic registers of the meteorological department. This piece of work has in itself involved considerable time and labour, though the final corrections to N.P.D. will in general be small; but the importance of the catalogue for comparison with "Stone's 1880 Cape Catalogue" and others, and the consequent investigation of refraction, has made it imperative that the greatest care should be taken to have accurate thermometer readings.

As regards discussions to accompany the catalogue, the meridian observations of the Sun from 1877–1886 have been reduced to a uniform system and discussed for correction to epoch, which has been found insensible.

The mean places of clock stars as found from groups of at least twelve hours' observation by the same observer have been compared with the catalogue places (which depend on all groups of more than six hours): the differences are almost insensible, the largest being $0^s{\cdot}007$ in the neighbourhood of 23^h R.A. In the case of the Nine-Year Catalogue (1872) the differences were more pronounced. It appears, therefore, that a distinct advance has been made towards eliminating the systematic errors of the R.A.'s of clock stars. The list of Mean R.A.'s of clock stars for 1889 already distributed to observatories is based on the 12-hour groups of the period 1877–1886.

The altazimuth observations of the Moon in the first and last quarters have been continued as before. The erection of a new photographic dome at the end of 1887 made it necessary to discontinue the observations of the collimator and of the mark on the Royal Naval College, which is now hidden by the new building, and during the last year the adjustments of the instrument have depended on observations of high and low stars. An opening has now been cut in the cornice of the altazimuth building to allow of a view of two distant church spires which since 1888, November 26, have been regularly observed as marks when visible, and also of a nearer church spire at a distance of 355 yards, which will be available for observation in foggy weather by means of a long-focus lens, now nearly completed.

Comet *a* 1888 (Sawerthal) was observed on 23 nights, and

Comet *e* 1888 (Barnard) on five nights, with one or other of the equatorials. Comet *e* 1888 has also been observed on eight nights with the transit-circle.

Ten disappearances and nine reappearances of stars occulted by the Moon have been observed, these numbers including six disappearances and eight reappearances on the occasion of the total eclipse of the Moon, 1888, January 28, to which reference was made in the last report. Fourteen phenomena of *Jupiter's* satellites have also been observed. The smallness of all these numbers is again due in some measure to the unfavourable weather.

The provision of a photographic telescope of 13 inches aperture with a 10-inch guiding telescope, to enable this Observatory to take part in the Photographic Map of the Heavens, was sanctioned by the Treasury at the end of August, and the construction of the instrument has been entrusted to Sir Howard Grubb. A number of photographs of stars were taken last summer with a 6-inch object glass made by Sir Howard Grubb, as an experiment preliminary to the construction of the 13-inch object-glass intended for work on the Photographic Chart; but the results are inconclusive, as it was found that one of the pieces of tinfoil between the lenses was missing, and that consequently the object-glass was not properly adjusted. The glass is now in Sir Howard Grubb's hands for slight modification previous to re-examination at this Observatory.

About twenty photographs were taken in June and July to demonstrate the practicability of transferring stellar images from the curved plates, of which mention was made in the last report, to flat plates, where they can be more readily measured with a micrometer. For this purpose, the Dallmeyer lens, with which the plates were originally taken, was mounted about the middle of a wooden tube 20 feet long (four times the focal length), and stopped down to two inches to diminish aberration. The curved original and the flat plate to receive the copy were placed at ends of the tube, diffused daylight being used in these operations. The results appear to be satisfactory, and indicate that the curved plate gives a flat field at the conjugate focus, as was expected.

Further micrometric measurements of the flat plates obtained with the Dallmeyer objective have confirmed the conclusion that star places can be obtained with sufficient accuracy over a field 4° square, for which the images are nearly round, and even outside this limit where the images become crosses or ellipses. In one case the places of 47 stars on the plate as photographed at three positions for focus, differing by 0·16 inch, or about one four hundredth of the focal length, were measured, to determine the effect of a change of focal length, when the exposure remains the same. In another instance two exposures (of 20^m and 5^m) were taken at the standard focal reading, and a similar pair at a reading differing by 0·10 inch; and the places

of each of 30 stars compared in the four cases. The results indicate that the places obtained are independent of a considerable change in focal length (allowance being made for change of scale), and of a considerable difference in exposure.

A satisfactory pair of discs for the 28-inch object-glass has at length been obtained from Messrs. Chance, and Sir Howard Grubb expects to have the object-glass completed by next October.

Observations with the half-prism spectroscope for the determination of the motions of stars in the line of sight were intermitted from the end of May until December, during which interval the single-prism spectroscope was used to examine the spectra of *α Herculis*, *β Lyræ*, *γ Cassiopeiæ*, *P Cygni*, *R Cygni*, *β Pegasi* and *Mira Ceti*. The spectrum of Comet Sawerthal was observed on three nights, and that of Comet Barnard on one. For determination of motion of stars in the line of sight, 106 measures of displacement of the F line have been obtained from the spectra of 26 stars, besides 25 measures of lines in the spectra of the Sun, Moon, or planets as a check on the adjustment of the instrument and general accuracy of the measures.

Attempts have been made to photograph the spectra of stars with the south-east equatorial. Some photographs of the spectrum of *Vega* have been obtained.

With the photo-heliograph, photographs of the Sun have been taken on 195 days, and 380 selected for preservation, including ten photographs with a double image of the Sun taken to determine the position of the wires with reference to a declination-circle. The additional photographs received from India and Mauritius leave only six days in the year ending 1888, November 16, on which no photograph is as yet available for measurement.

One hundred and eighteen photographs taken at Harvard College, Cambridge, U.S., between the dates 1874, December 9 and 1875, August 31, have been received from the Solar Physics Committee; of these 55 have been measured and reduced to fill up gaps in the Greenwich Series.

Ten photographs taken at Ely, between the dates 1874, January 1 and February 15, have also been received.

In 1885 a series of measures was made of a set of 8-inch photographs for the determination of the probable error of a single measure of distance, position-angle, and area. During the past year a corresponding series has been made on 4-inch photographs, and on comparison of the two it is found that measures of distance and position-angle are about twice as accurate with 8-inch pictures, the magnification having its full advantage; but that measures of area are not sensibly more accurate with 8-inch than with 4-inch pictures, the gain by magnification being apparently counterbalanced by loss in definition

In the period September 23 to November 15 observations were made in concert with French officers of the Service Géographique de l'Armée to re-determine the longitude Paris-Greenwich. A previous determination of this longitude in 1854 by M. Faye and Mr. Dunkin, using eye-and-ear methods both for star observing and signals, gave a value which appears to be about $0^s.5$ too small on comparison with subsequent observations, more or less indirect, although the accordance of the separate nights among themselves was excellent, and indicated a result which might be accepted with some confidence. It was therefore a matter of importance to re-determine this longitude with modern instrumental improvements and by several observers. A wire was kindly put at the disposal of the Observatory by the Submarine Telegraph Company for the requisite period, and arrangements were made by the Post Office Telegraphs for direct communication with Paris. Observations were made in four groups of three full nights each (or the equivalent in half-nights). An English and a French observer were stationed at each end, each with a separate instrument and chronograph, and the pairs of observers were interchanged twice. The pairs of English and French instruments were similar, and the chronographic method was used both for recording star transits and signals. On a full night each observer recorded about forty star transits, reversing his instrument three times, and exchanged signals twice (near the beginning and the end of the evening) with his compatriot at the other end of the line, and once with the other observer. The actual stations were the front court of the Royal Observatory (in the meridian of Bradley's transit, and a few feet only from that of the transit-circle) and the Observatory of the Service Géographique at Paris, whose position with respect to the Paris Observatory has been accurately determined. Commandants Bassot and Defforges were the French observers, and Mr. Turner and Mr. Lewis the English.

While stationed at Greenwich Commandant Defforges took the opportunity of swinging his reversible pendulums, to determine the absolute force of gravity. The Indian invariable pendulum has recently been mounted under General Walker's supervision in the Record Room at Greenwich for observations similar to those already made in India and at Kew. By these two operations the French and Indian pendulum determinations will be connected through Greenwich.

The enlargement of the computing-rooms referred to in the last report was completed in April, and the new 18-feet dome has been built over them. No instrument has as yet been mounted there, the intention being to reserve the site for the new photographic refractor.

The volume of Greenwich *Observations* for 1886 and the *Spectroscopic and Photographic Results* for 1887 were distributed last September, and the printing of other results in 1887 is well advanced.

Royal Observatory, Edinburgh.

On August 15, 1888, Professor C. Piazzi Smyth resigned the posts of Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh, which he had held for forty-three years. On January 29, 1889, Her Majesty was graciously pleased to appoint Ralph Copeland, Ph.D., to succeed Professor Smyth in the double capacity. In the interim the charge of the Observatory devolved upon Mr. Thomas Heath, First Assistant Astronomer, who, with the aid of Mr. James Forgan, acting Second Assistant Astronomer, has carried on the reductions and observations unremittingly and most efficiently up to the present time. These have consisted of:—

(*a*) The computation of the monthly schedules of the twice-a-day observations at fifty-five of the stations of the Scottish Meteorological Society, and their comparison with the means of the last thirty-two years, for the use of the Registrar-General, who has published them in his printed reports.

(*b*) Observations of the barometer and three thermometers in different exposures, recorded with the usual weather-notes at 1 P.M.

(*c*) Weekly readings of the rock thermometers at depths of 21 feet, 10 feet, 4 feet, and 2 feet, as detailed in Professor Smyth's final report to Her Majesty's Secretary for Scotland. On June 30, 1888, two essays were completed at the Observatory and communicated to the Royal Society of Edinburgh, in addition to the one on the 24-inch equatorial reflector mentioned in last year's report; they are:—"Mean Scottish Meteorology for the last Thirty-two Years," and "Eight Years' Observations of the New Earth Thermometers." The first-mentioned paper contains thirty-one tables of monthly and annual mean results of Scottish meteorology, with fourteen plates of curves. The paper on the earth thermometers contains four tables, with three supplementary tables and four plates of curves.

These two papers have been printed and published by the Royal Society of Edinburgh, the proofs having been, for the most part, revised at the Observatory, and posted to Professor Smyth for final examination before going to press.

The whole of the buildings and instruments are in a condition similar to that in which they were at the above-mentioned date. No alterations or improvements have been made, with the exception of a complete re-painting of the outside wood-work and the dome of the Observatory, and a much-needed new arrangement for the water supply at the First Assistant's residence, carried out in the autumn by W. W. Robertson, Esq., of H.M. Office of Works.

Considering the present condition of the Observatory, no

new scientific work has been undertaken, but the usual observations of clock stars, and occasionally of the Sun when necessary, with the transit instrument, have been regularly carried out for the purposes of the daily signalling by time-ball, time-gun, and electrically controlled clocks. All the instruments connected with these duties are in a state of complete efficiency. No official appointment to the post of Second Assistant Astronomer has been made since the resignation of Mr. H. W. Ride in February 1888, but, in order to carry on the work of the Observatory, Mr. Heath has been allowed to engage Mr. Forgan's services as temporary Second Assistant, and arrangements have been made by the Exchequer Office for the payment of his salary. In consequence of the assiduous attention which Mr. Forgan has devoted to his duties at the Observatory, this plan has worked in every way satisfactorily.

The original drafts of the MSS. of the unprinted Spectroscopic volume, prepared with so great expenditure of labour by Professor Smyth, still remain deposited in the computing room of the Observatory, the printer's copies being in Professor Smyth's care at his residence.

In the autumn of 1888 the Lords Commissioners of Her Majesty's Treasury accepted the princely gift made to the nation by the Earl of Crawford and Balcarres of the whole of the instruments and equipment of the Dunecht Observatory, for the better outfitting of a new royal observatory, to be built and maintained on a suitable site near Edinburgh. The value of this gift may be gathered from the following abstract of the Dunecht inventory:—

	Number of pieces.
A. Telescopes	16
Including the 15-inch equatorial and the 8·6-inch transit-circle.	
B. Telescope accessories	25
C. Domes, huts, &c.	9
Amongst these are several huts well suited for field work.	
D. Stands, piers, and furniture	57
E. Clocks and chronometers	19
Of these two are compensated clocks, and six are first-class box-chronometers.	
F. Thermometers and barometers	32
Including the King's barograph.	

G. Optical apparatus in seven divisions :—	Number of pieces.
a. Lenses	13
b. Mirrors	4
c. Diffraction apparatus	8
d. Special objects made of quartz	7
e. Prisms	24
f. Polarising apparatus	10
g. General optical appliances	21
	87

Many of these numbers represent complete groups of apparatus for special studies; e.g. in *c.* is a set of the contrivances devised by Schwerd for his classical researches on diffraction.

H. Photographic apparatus	28
I. Electrical and magnetical apparatus	68
J. Small instruments and miscellaneous appliances	61
K Spectroscopes and accessories	22
L. Measuring bars, &c.	16
M. Tools and materials	37
N. Library of upwards of 15,000 printed books and pamphlets, MSS., engravings, &c.	

The printed catalogue of books and pamphlets extends to 485 pp. of two columns, in 4to. A list of the MSS. is being prepared for the press.

When to this admirable collection is added the 2-foot silver-on-glass reflector now at Calton Hill, which it is hoped may be remodelled on the lines devised by Professor Piazzi Smyth, Scotland will possess the instrumental outfit of a first-class national observatory.

The broken nature of the ground around Edinburgh gives considerable scope in the choice of a favourable site for the new observatory, and negotiations have for some time been in progress for securing a desirable piece of ground about three miles from the heart of the city. Respecting the proposed new buildings, it can only be said at present that the 22-foot dome now at Dunecht will be re-erected for the relatively short 24-inch reflector, while a new and larger dome will be provided for the 15-inch equatorial; and that a new meridian house of iron and wood, designed to afford the most perfect ventilation, will cover the transit-circle and its collimators. The fact that the new buildings will be constructed by H.M. Office of Works is an ample guarantee that they will be satisfactory in every respect.

With the erection of the new Royal Observatory, thus to be

brought about by the munificence of Lord Crawford, it is hoped that a vigorous impetus will be given to the study of astronomy in Edinburgh, and that arrangements may be devised by which students will have every facility for becoming acquainted with the practical details of observational astronomy as well as the fundamental principles of the science.

The present Royal Observatory was visited on October 10 by a committee of several members of the Edinburgh Town Council, headed by Lord Provost Sir Thomas Clark, Bart., for the purpose of examining the buildings and instruments in view of the offer made by H.M. Government to transfer the buildings and certain of the instruments to the town on the completion of the new Observatory buildings.

A similar visit was made on October 26 by Lord McLaren, Professor P. G. Tait, and W. W. Robertson, Esq., to examine and value the instruments on behalf of the Exchequer, for the purpose of the proposed transfer.

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Royal Observatory, Cape of Good Hope.

During a great part of the year 1888 the weather was exceptionally unfavourable for astronomical work. The rainfall at the Observatory was 36·06 inches, as compared with 23·08 inches in 1887, and with 24·81, the mean of forty-two years. This was accompanied by a still greater percentage increase of cloud, especially during the period April to October. Observations with the transit-circle have been continued regularly throughout the year. The chief objects of observation have been the Sun, *Mercury*, and *Venus*, stars in the list of the Cape 10-year catalogue for 1890, comet comparison stars, stars occulted by the Moon, stars employed in the latitude and longitude determinations of the geodetic survey of South Africa, and stars employed in zones for determining the scale-value of the heliometer. In addition, the minor planet *Iris* and the selected comparison stars were regularly observed between October 12 and December 13.

The work accomplished in 1888 has been as follows:—

Number of determinations of collimation	52
" " level	372
" " nadir	383
" " runs	378
" " flexure	64
Number of observations of meridian mark	374

	Direct.	Reflex.
Number of observations of stars in R.A.	4947	156
" " " N.P.D.	4576	155
Observations of both limbs of the Sun in both elements	118	
Observations of *Mercury*	64	
" *Venus*	90	
" *Iris*	32	

The work with the great theodolite has been limited, from the want of an available assistant, no observing computer having been available for any kind of observing during the year, and the services of Mr. Pett having been devoted to the zenith telescope. Thus there have only been observed with the theodolite—

Azimuths of pairs of N. stars for latitude (Kapteyn's method)	12
Observations of azimuth marks	2
Determinations of runs	4

With the zenith telescope 849 pairs of stars have been observed by Talcott's (Horrebow's) method, partly in connection with Kapteyn's method of latitude determination, partly for control on the law of flexure of the transit-circle, and for the connection of the northern and southern systems of declination.

The following occultations of stars by the Moon have been observed:—

Disappearance at bright limb		0
Reappearance at bright limb		1
Disappearance at dark limb		18
Reappearance at dark limb		8
During Total Eclipse of Moon, 1888, January 28	Disappearance	11
	Reappearance	11
	Total	49

On February 18, in the early morning, a comet was detected in the constellation *Telescopium*, by Mr. H. Sawerthal, whilst he was engaged in exposing photographic plates in connection with the work of the southern *Durchmusterung*. The comet was observed with the equatorial by Mr. Finlay on seventeen mornings, and by Dr. Gill with the heliometer on five mornings, between February 18 and March 17 inclusive. The Warner prize of 100*l.* has been awarded to Mr. Sawerthal for his discovery.

Photographs of the comet were obtained on February 20, 24, March 9, 12, 13, 17, which will be presented to the Society, together with definitive results of the observations.

From the progress made in the early part of the year by the constant employment of two observers, it was anticipated that the photographic work of the *Durchmusterung* would be completed early in 1889, but the exceptionally clouded state of the sky in the months of April, May, and June made it impossible to complete the photography of the zones which culminate at night during these months.

During the year 885 plates have been exposed—

17	in attempts to photograph ☄ Sawerthal,
746	passed for measurement in connection with the *Durchmusterung*,
110	deficient on account of haze, cloud, or fogging of the object-glass,
12	useless and entirely rejected.
Total 885	

The measurement of the plates is being rapidly and successfully pushed forward by Professor J. C. Kapteyn. The photographic part of the work will probably be completed in June 1889, and it is confidently anticipated that the complete *Durchmusterung* will be ready for press within three years.

The progress of working with the heliometer was at first greatly delayed by the inconvenience and inefficiency of ordinary batteries as a source of electric light for its illumination. By the liberality of the Lords Commissioners of the Admiralty, provision was made for an efficient dynamo capable of supplying electric light not only for all the instruments and offices but for the houses of H.M.'s Astronomer and Chief Assistant also (the latter houses form part of the main observatory building). The necessary plant for carrying out the illumination of the observatories, instruments, and computing-rooms was sent out early in February, and was completely installed and at work before the end of the month. Every separate observatory has now its own group of accumulators, each observatory and each instrument is illuminated by the electric light; and the immense advantages of this light for astronomical purposes can only be fully appreciated by those who have practically experienced it.

In each of the detached observatories six-volt lamps are employed, supplied by three cells of 350 ampere-hours capacity. In the main building, including the library, computing-rooms, and transit-circle, a group of twelve cells of similar capacity is used, with lamps of twenty-four volts. The whole of the accumulator groups in the various observatories are charged *in situ*, in series, once a week, each group being switched out as it becomes fully charged, so that there is no waste of energy from undue overcharging. The system has been entirely successful, and has worked without trouble or failure of any kind since its installation.

Previous to the definitive installation of the electric light regular work with the heliometer could not be efficiently under-

taken. A large number of observations of scale-value zones, &c., were made, and many necessary preliminary investigations and experiments were carried out.

Regular researches on stellar parallax were begun in the end of February. Considerable difficulty was found in arranging a programme such that, on the one hand, as little time as possible should be lost, and, on the other hand, that its full execution should not clash with the heliometer observations of *Iris* in the mornings of October, November, and December 1888, or with the observations of *Victoria* and *Sappho* planned for June, July, August, September, October, November, and part of December 1889. A further difficulty was created by the exceptionally cloudy weather of April, May and June, which defeated the intended commencement of some additional series. The following stars have been observed for parallax by Dr. Gill with one pair of comparison stars each, at each of two periods of maximum parallactic displacement in distance, and generally with six nights' observations at each period:—

β Hydri	*Sirius*	*β Centauri*
α Eridani	*β Crucis*	*α Gruis*
β Orionis	*α Virginis*	*Fomalhaut*
Canopus.		

The third period of maximum displacement for each of these pairs can be observed without interfering with the projected observations of *Victoria* and *Sappho* in 1889.

α Crucis has only been observed at one period, viz. in July, but it is hoped to be possible to obtain the July observations of 1889 without undue interference with the observations of *Victoria*. The observations of January 1889 will of course present no difficulty.

Observations which were begun on *τ Ceti*, and on second pairs for *Canopus* and *β Crucis*, had to be dropped.

Mr. Finlay has observed *α Scorpii* at one period of maximum displacement, and it will probably be possible to secure observations at two successive epochs (March and September 1889) without interference with the existing programme.

At the meeting of the Paris Astrophotographic Congress in 1887, preliminary arrangements were made between Dr. Elkin and H.M. Astronomer at the Cape for simultaneous observation of the minor planet *Iris* during its opposition in the months of October, November, and December 1888. The observations were to be made simultaneously at both observatories when the planet is in a plane passing through both observatories and the centre of the Earth. In other words, the angles between *Iris* and two stars (one above and one below the planet) were to be observed at both observatories when the planet was two hours west of the meridian at the Cape and four hours east of the meridian at New Haven. As the difference of longitude is 6^h,

the observations become practically simultaneous. Afterwards Dr. Bruns joined in the scheme with the Leipzig Heliometer. Full reports of the observations obtained at New Haven and Leipzig have not yet been received. At the Cape observations have been secured on forty-four mornings, as follows :—

Observer: Gill.	Observer: Finlay.
Oct. 12, 14, 21, 22, 24, 26, 29, 31	Oct. 13, 15, 21, 25, 27, 30
Nov. 2, 4, 5, 7, 9, 11, 13, 19, 21, 23, 29	Nov. 3, 6, 10, 12, 18, 20, 22, 24, 28, 30
Dec. 3, 5, 7, 9, 10	Dec. 2, 4, 6, 8

The observations of *Iris* at the Cape include about 1,000 bisections of the planet, all the observations having large parallax factors. Should the New Haven and Leipzig series include corresponding observations of even half that number, a very reliable value of the solar parallax will result.

An ephemeris of the planet and places of the comparison stars were distributed to the observatories at Greenwich, Dublin, Oxford, Melbourne, Cordoba, and Pulkowa, the directors of which cordially promised co-operation, and Dr. Auwers has secured the further co-operation of several German observatories. The discussion of these observations should insure an ephemeris of the planet sufficiently exact for the accurate reduction of the observations. Plans have been prepared for more complete and elaborate observation of *Victoria* and *Sappho* in June to December 1889. These plans involve the co-operation of the heliometer at Yale, Leipzig, Gottingen, Bamberg, and the Cape. Details of these plans will afterwards be communicated, and requests made for the co-operation of meridian observatories.

An account of the process of determining the errors of the scales of the heliometer has been communicated to the Society. The operation now progresses steadily at the rate of the complete inter-comparison of 10 divisions on each scale per week. But as each determination is controlled by an independent series derived from comparison with a different part of the other scale, the real progress is virtually only 10 divisions on one scale per week. There are in all 180 divisions on each scale—fully one-third of the whole work is now accomplished. The greatest discordance between any of the two independent determinations of the error of any single division is $0''\cdot030$. The complete operation involves over 45,000 bisections, but the detection of several accidental errors of division amounting to $0''\cdot2$, and many amounting to $0''\cdot1$, justify the necessity for this tedious and laborious undertaking.

The errors of the scale micrometer screw have been thoroughly determined.

During the past year the field work of the Geodetic Survey has been suspended, and Major Morris, R.E., has been engaged at the Observatory in the reduction of the results. The bars

used in the measurement of the base-lines at Natal and Port Elizabeth have been thoroughly compared with the Cape 10-foot standard bar A, the constants of which were determined at the International Bureau of Weights and Measures. For this purpose a *Comparateur*, devised by H.M. Astronomer, and constructed by Troughton & Simms, has been mounted in the S.E. room of the Observatory, and fitted with the necessary controlled hot and cold water supply. With this apparatus each of the five Cape base-bars have been compared with the standard bar, the latter being kept at a nearly constant temperature of 60°, whilst the former were compared with it at 50°, 60°, 70°, 80°, and 90° F., both at fixed temperatures and at gradually ascending and descending temperatures, in exact imitation of the increments encountered in the field. The probable error of a comparison at each temperature is about 1 *micron*.

With the new constants of the measuring-bars the lengths of the base-lines have been re-computed.

The Natal base was measured in three sections, each section being measured forwards and backwards. The results are:—

	I.	II.	III.
	Metres.	Metres.	Metres
Forwards .	1097·33764	1097·35875	1097·58438
Backwards .	·33897	·35920	·58322
F−B . .	− ·00133	− ·00045	− ·00116

The Port Elizabeth base was measured in eight sections, each section being measured "forwards" in the morning (that is, with increasing temperature), and "backwards" in the afternoon (that is, with falling temperature), with the following results:—

	I.	II.	III.	IV.
	Metres.	Metres.	Metres.	Metres.
Forwards .	213·36952	213·37356	213·37512	213·36440
Backwards .	·36924	·37359	·37439	·36423
F−B . .	+ ·00028	− ·00003	+ ·00073	+ ·00017
	V.	**VI.**	**VII.**	**VIII.**
Forwards .	213·36525	213·36625	213·36168	213·35685
Backwards .	·36571	·36604	·36232	·35674
F−B . .	− ·00046	+ ·00021	− ·00064	+ ·00011

Hence the probable errors of the measurement of the two bases, apart from the systematic error in the length of the bars, are:—

	Inch.
For the whole Natal base	± 0·024
Port Elizabeth base	± ·015

These results prove the efficiency of bent thermometers having their bulbs in mercury-wells to indicate truly the temperature of steel bars used in the field, provided that each bar is protected by a wooden casing with ample air-space, and these cases in turn protected from direct sunlight by portable huts such as were employed on the Natal and Port Elizabeth base-lines.

The two base-lines are connected by a nearly direct chain of 50 triangles, measuring 450 miles in length along the centre of the chain. Of these triangles 31 form parts of polygonal figures, and 19 are triangles forming a simple chain. In the first place, the angles of the whole of the polygonal figures were rendered rigidly consistent by the method of least squares, and the angles of the isolated triangles made equal to $180° + \epsilon$. The length of the Port Elizabeth base was then computed through the chain of 50 triangles from the Natal base, and found to differ 1·94 inch from its directly observed length. The small corrections applicable to the angles of the intervening triangles to equalise the computed with the observed lengths of the bases were then calculated by Clarke's method, the whole of the corrections being thrown upon the angles of the isolated triangles. When the angles of the 123 triangles (which constitute the whole work) were thus finally corrected and compared with the uncorrected angles as originally measured, the square root of the mean of the squares of the differences was found to be

$$\pm 0''\cdot 56$$

so that the probable error of an observed angle throughout the principal triangulation is

$$\pm 0''\cdot 38$$

In the prolongation, by triangulation, of the Port Elizabeth base to three times its measured length, the angles were observed at night. The station points were marked by small holes in discs micrometrically adjusted vertically over the dots marking the stations, and these holes, illuminated by bull's-eye lanterns, were observed as artificial stars. In the twenty-four triangles of this extension, which are not included in the above-mentioned 123 triangles, the *mean error* of a single angle has been similarly found to be $\pm\ 0''\cdot 25$, or the probable error

$$\pm 0''\cdot 17$$

The comparison of the astronomical latitudes, longitudes, and azimuths with the corresponding geodetic quantities (Clarke's elements) is now in progress, and will be completed early in 1889. A remarkable case of abnormal deviation of the plumb-line has been found at Port Elizabeth, and will be further investigated.

A reconnaissance survey for an arc of meridian connecting Port Elizabeth with Kimberley and Bechuanaland is in progress.

Major Morris leaves the Observatory in February to make further latitude determinations at stations surrounding Port Elizabeth, and will then re-measure a longitude chain of Baily's triangles connecting Maclear's work with the new triangles of the Geodetic Survey.

A new catalogue of 104 southern circumpolar stars, depending on the results of a very large number of double transits made in the years 1881 to 1888, has been prepared, and will soon be ready for press. The places of this new catalogue have been employed for computation of the azimuths of the transit-circle from 1885.

The Cape Catalogue of 1,714 stars, reduced to the equinox of 1885, depending on the results of the Cape meridian observations from 1879 to 1885, is now ready, except the application of final systematic corrections dependent on latitude flexure and refraction, for the full discussion of which the results of Greenwich and Leiden corresponding observations are awaited, as well as some further zenith telescope observations.

The preliminary results for the places of the fundamental stars of Schönfeld's *Durchmusterung* have been communicated in MS. to Dr. Auwers.

Miss Agnes M. Clerke, well known to astronomers by her "History of Astronomy in the Nineteenth Century," visited the Observatory during September and October, and besides carefully studying its practical working, made some original observations on the spectra of southern stars.

The Lords Commissioners of the Admiralty having sanctioned the acquisition of a suitable photographic telescope to enable the Observatory to take its share in the working programme of the Astrophotographic Congress of 1887, the telescope and dome have been ordered from Sir Howard Grubb, and the building of the Observatory has been commenced. The whole will probably be in working order before the end of 1889.

The meteorological observations made in the year 1887 at the Observatory, together with those taken in different parts of the colony, have been printed in the Report of the Cape Meteorological Commission.

Armagh Observatory.

After the completion of the Catalogue of Nebulæ the micrometrical observations of these objects were resumed with the 10-inch refractor. Differences of right ascension and declination with neighbouring stars which have been observed on the meridian are determined either with a filar micrometer, or by taking transits over a steel bar (without any illumination) inclined alternately at an angle of 45° and 135° to the parallel. This modification of Boguslawski's micrometer is very conve-

nient and the reductions are very simple; it was suggested by Professor Vogel, and is described in the *Astr. Nachr.*, No. 2835.

The occultations observed during the lunar eclipse of January 28 were published in the *Monthly Notices* for March 1888.

Cambridge Observatory.

This year has been exceptionally unfavourable for observations. Clock stars were observed on 117 nights, but of these only 64 nights were suitable for the observation of zone stars. The total number of observations for clock correction is 550. *Polaris* was observed above the Pole, directly 45 times, and by reflection seven times; below the Pole, directly 60 times, and by reflection 30 times; making in all 142 observations of *Polaris*, which involved 308 circle readings. The number of zone stars was necessarily limited, and consisted chiefly of very small stars which required a third observation, and stars in which discrepancies had been found in the formation of the Catalogue. The total number amounts to 860. Stars which had been compared with *Sappho* were observed 58 times; stars in the path of *Iris*, 108 times; and *Iris* itself, 16 times. Thus the entire number of meridian observations is 1,734. One hundred and twenty-four observations of each collimator, after adjustment horizontally, involving, of course, 248 circle readings, were made to obtain the coefficient of flexure.

The nadir point, level, and collimation were each determined 213 times.

The calculations of true right ascension and true north polar distance of all the stars are nearly completed up to December 1. The reduction to mean right ascension and mean north polar distance for January 1 of each year is completed to the end of 1883. The right ascensions are reduced to the epoch 1875 till the end of 1881, the north polar distances till the end of 1883.

The collection of zone observations for formation of Catalogue, from five hours R.A. to nine hours, is nearly completed till the end of 1878.

The observations of occultations of small stars by the Moon during the total eclipse of January 28 was an almost utter failure. The sky was clouded all the time, with occasional very imperfect breaks. In the few glimpses which were obtained of the Moon two emersions only were observed, and these not reliable, as it was by no means certain whether the appearances were owing to the clouds passing away or to the emergence of the star from behind the Moon. A list of 61 stars had been prepared, and arrangements made by which we hoped, with the aid of the square-bar micrometer, to secure nearly all of them. The two reappearances occurred at the very places where the observer was looking.

By request of Mr. Bryant the planet *Sappho* was observed

near the opposition with the Northumberland equatorial and square-bar micrometer. On four nights in April, 26 comparisons with selected fixed stars were obtained. The results were very consistent. The compared stars were subsequently observed with the meridian circle.

The observations for flexure of transit telescope are only partially reduced. The coefficient from 20 observations made on 20 separate days, June 20–July 13, is $-0''\cdot50$; precisely the same as that which was obtained from 200 observations made in 1885, May 29–July 17. That is, the arc from north horizon through zenith to south horizon is $180^\circ\ 0'\ 1''\cdot00$—according to the circle readings, instead of 180°. The correction of the circle reading for flexure, supposing it to vary as the sine of the zenith distance, will therefore be $-0''\cdot50 \sin z$, where z is the zenith distance, + when S, − when N.

The mean of 73 observations of *Polaris* above the Pole, made in 1887, reduced with assumed colatitude $37^\circ\ 47'\ 8''\cdot4$, and corrected for errors of division and flexure, give, for the correction of the Berlin N.P.D., $-0''\cdot41$, and 68 observations below the Pole give $+0''\cdot67$. These results give, for the correction of the Berlin N P.D., $+0''\cdot13$, and for the correction of the assumed colatitude, $+0''\cdot54$, making the colatitude $37^\circ\ 47'\ 8''\cdot94$. The observations of 1886 gave 8·96. Ten years—1878–1887—give 8·87.

Assuming the places in the *Berliner Jahrbuch* correct, 738 observations of clock stars made in 1887, not corrected for errors of division or flexure, give for the colatitude $37^\circ\ 47'\ 8''\cdot883$.

In the case of *Polaris* above and below the Pole, the errors of the divisions actually read off, compared with the reading of the nadir point, had been carefully determined. This has not been done for each individual clock star.

A few additional determinations of latitude have been obtained from direct and reflected observations of *Polaris*; but the entire series has not yet been discussed.

On September 12 Faye's Comet was sought for until daybreak with the Northumberland equatorial, in a perfectly clear sky, at and around the place given in the *Ast. Nach.*, No. 2856. No trace of it could be seen. This was the second morning that we had tried and failed. On the former occasion the sky was not so good; this morning it was perfect. The star DM $+17^\circ1275$, 6·3 mag., which was chosen as a comparison star and as our guide, has a very minute companion quite close s.f.

Several computers have drawn on us for places of small stars included in our zone, and we have been able satisfactorily to meet the demand.

Dr. Bernhard Schwarz, assistant in the Prague Observatory, has undertaken a recalculation of the orbit of Comet 1847 VI., sometimes called Miss Mitchell's Comet, and sometimes Dawes' Comet, for which Rümker found a hyperbolic orbit. He sent to ask for the data from which Professor Challis determined the places for October 11 and 12, published by him in the *Monthly*

Notices, vol. viii. p. 25. These have been found and recalculated by Mr. Graham, who has also found the two comparison stars of October 12 in the zone observations, each taken three times with the transit circle. All the details have been forwarded to Dr. Schwarz.

On April 5 a fresh determination of the intervals of the transit wires, from 101 observations of *Polaris* made in 1887, was completed. As this differed very slightly from the previous determination from 78 observations, and no accident has happened to the wires for several years, the two were combined, giving them the weights 9 and 7 respectively, and the necessary tables formed from the result.

A determination of the intervals has also been made from a large number of clock stars, but the results require re-examination.

On June 23 the object-glass of the transit telescope was taken out, and the lenses were separated and cleaned by a workman from the factory of Mr. Simms. A few spots had shown themselves between the lenses, but these were easily removed, and it was found that the lenses had suffered no damage. The line of collimation and nadir point were, of course, altered by the operation.

Dunsink Observatory.

The observations of the zenith distance of *Polaris* for determining the latitude of this Observatory, which were in progress at the date of last report, were brought to a close towards the end of January 1888. A discussion of the complete series gives for the value of this quantity 53° 23′ 13″·2, which differs from the value hitherto employed—that of Dr. Brünnow—by the one-fifth of a second. The latitude was also deduced from a number of observations of Auwers's stars, adopting their places as given in the *Berliner Jahrbuch*, and this result, combined with that derived from the *Polaris* series, gives 53° 23′ 13″·1. An account of the whole series of observations and the individual results is given in a paper read before the Royal Dublin Society in November, which will shortly be published.

During the spring and summer months systematic work with the meridian circle was discontinued, but early in September we received from Dr. Gill a list of the comparison stars which he proposed to use for heliometer observations of *Iris*. Work was at once commenced on this list, but, owing to the unpropitious skies which prevailed in October and November, its completion was very much delayed, and the last observation required was not obtained till the 10th of January, 1889. We have obtained from four to seven observations of each of the thirty stars on the list, and the results appear to be satisfactory. Their places have been referred, both in right ascension and declination, to a

few selected stars of the *Berliner Jahrbuch* which culminate immediately before and after the stars of Dr. Gill's list, and at about the same altitude.

These observations have been fully reduced up to December 26, so that it is hoped that the results will soon be ready for publication. At the same time we obtained 27 meridian observations of what was taken for the planet *Iris*. At first there was no difficulty found in its identification, but as the brightness diminished towards the end it is possible that one or two of the last few observations may prove to have been made on other stars, as it was sometimes difficult to decide which object in the telescope was the planet before it reached the wires.

The meridian circle has also been employed during the year for observing stars in connexion with the time service to Dublin.

On the night of January 28 the "South" equatorial was used, with the chronograph, for observing occultations of stars during the total eclipse of the Moon. Of these 17 disappearances and 18 reappearances were observed, of which a detailed account appeared at the time.

The "South" equatorial has also been employed as usual throughout the year in observing stars for parallax. Of these, 115 complete series of micrometric measures have been made.

Early in the year the Sixth Part of the "Dunsink Observations and Researches," containing the results of observations on 1,012 southern stars made with the meridian circle, was distributed as usual.

A 15-inch reflector, adapted for photographic work, has been presented to the Observatory by Mr. Isaac Roberts. It is about to be mounted in the small dome for the continuation of Parallax work by photography.

Glasgow Observatory.

The astronomical operations at the Glasgow Observatory during the past year have been mainly confined to the re-observation of a selected list of stars in the Glasgow Star Catalogue, the discordances between the places of which and those of Weisse's Bessel appeared to be greater than the ordinary errors of observation would warrant. It is expected that these observations will be brought to a close towards the end of the present year.

Kew Observatory.

The ordinary routine of meteorological and magnetical observations has been carried out during the year without alteration, and large numbers of scientific instruments have undergone examination as usual.

The sketches of Sun-spots, as seen projected on the photoheliograph screen, have been made on 150 days, in order to continue Schwabe's enumeration.

Regular observations of solar and of sidereal transits have been taken, for the purpose of keeping correct local time at the Observatory, and the clocks and chronometers have been compared daily; but in addition to this, with a view of obtaining the time at the Observatory for pendulum work to a high degree of accuracy, and also for comparing daily the time as determined by the Observatory transit with that distributed by the Postmaster-General from St. Martin's-le-Grand, a telegraph line has been set up, placing the Observatory in direct electrical communication with the chief post office in Richmond.

A relay and chronograph have been purchased and placed in the circuit, and every morning, excepting Sundays and holidays, the 10 A.M. signal from the Royal Observatory, Greenwich, is recorded beside the beats of the Observatory standard clock (French) on the same tape. The signals have been observed daily by means of the galvanometer for the past two months, but the chronograph was only regularly set to work on October 31, delay having arisen on account of the necessity of protecting the apparatus from lightning.

The cost of the chronograph and attachments to the standard clock has been defrayed by a grant from the Royal Society.

Experiments were made during November and the early part of December to determine the time of vibration at pressures of 2 and 27 inches respectively of the Indian invariable pendulums Nos. 4, 11, and 1821, recently swung by American observers in different localities. After 14 sets of swings had been made with each pendulum, the apparatus was dismounted and wholly transferred to the Royal Observatory, Greenwich, where it is intended to repeat the swinging operations during the spring.

The vacuum correction of the two thermometers used on the dummy has also been determined. It was observed that a reduction of 27 inches in the barometric pressure lowered their zero points by $0^{\circ}\cdot25$. Other observations were also made to find the relative degree of accordance during changes of temperature between the indications of the thermometers in the interior of the vacuum chamber and that attached to the Richard thermograph, placed in close proximity to its outer surface.

During the experiments the holding capacity of the chamber was thoroughly tested, and found to stand low pressures extremely well.

Old Mural Quadrant.—When in 1840 the astronomical instruments forming the equipment of George III.'s Observatory were removed to Armagh, it was found impracticable to take away the 8-foot mural quadrant by Sissons on account of its being too large to pass through the doors or windows of the room in which it was placed. Recently, advantage was taken of the removal of the roof of the east wing of the Observatory to

hoist it out and convey it to the Stores in the Office of Works at Kew, where it is now deposited. The Committee propose its ultimate consignment to the Loan Collection of Scientific Apparatus at South Kensington.

Liverpool Observatory, Bidston, Birkenhead.

The work has been carried on on the same lines as heretofore.

A large number of new chronometers have been tested during the past year in addition to those received from owners and masters of vessels frequenting the port of Liverpool. The test-certificates supplied with the instruments on their removal from the Observatory have been such as to enable the temperature corrections to be determined. The officers of the Pacific Steam Navigation Company have been furnished with the errors, and probable rates for each five degrees of Fahrenheit, from 45° to 95° inclusive, of their chronometers for the ensuing voyage.

Greenwich Mean Time has been communicated to the port daily, Sundays excepted, by the firing at 1 P.M. of the gun at the Morpeth Dock.

The meteorological work has proceeded as in previous years. No interruption has occurred in the records of the self-registering instruments.

Radcliffe Observatory, Oxford.

The following have been the subjects of observation during the year 1888:—

With the Transit Circle:—

(1) Observations of stars to the seventh magnitude inclusive between 115° north polar distance and the equator.

(2) Observations of the Moon, which are continued throughout the lunation and regularly compared with the right ascensions and north polar distances from Hansen's Tables. The mean error of Hansen's Tables for the period 1847 to 1863 amounted to $-1''\cdot30$, and there was no appearance of progressive increase; but with the mean solar times as now usually computed the mean error has progressively increased at the rate of $0''\cdot73$ per annum since 1864, and now amounts to $+17''\cdot7$.

(3) Observations of the Sun.

The following table gives the number of observations made during the year:—

Transits, 1,952.
Circle observations, 1,436.

These totals include :—

Observations of the Moon on 44 days.
" " Sun " 34 "
118 determinations of Nadir Point.
5 vertical diameters of the Moon.
Comet (Barnard, September 2) on November 16, 20, 22, and 27.
The planet *Iris* on 18 days.
52 observations of 29 *Iris* comparison stars.
Observations of 2 *Sappho* comparison stars.

With the Barclay Equatorial :—

24 observations of 12 double stars.
10 " Comet (Sawerthal).
4 " " (Barnard, September 2).
1 observation " (Barnard, October 30).

Observations of occultations of stars during the total lunar eclipse, 1888, January 28.

Observations of these occultations were also made with the heliometer and the old seven-inch equatorial.

With the Heliometer :—

During the period October 10 to December 13 the heliometer was employed in the observation of *Iris* and its comparison stars, in accordance with a scheme of combined operations forwarded by Dr. Gill, but the weather was generally very unfavourable for the observations, which required a clear sky for several consecutive hours; and although observations were made on 17 nights, complete sets of observations with the instrument on both sides of the pier were obtained only on five nights.

The unusual prevalence of cloud during the year 1888 seriously interfered with the work of the observers, although special watches were put on to secure observations during the early mornings.

The volume for the year 1885 has been nearly passed through the press, and will soon be distributed.

The reductions for 1887 and the north polar distance results for 1888 have been completed; the right ascension reductions for 1888 are in a very forward state.

The meteorological observations have been carried on with the usual completeness, and include photographic registration of the changes of the barometer and dry and wet bulb thermometers.

University Observatory, Oxford.

The work at the Oxford University Observatory has proceeded steadily on its former lines. The press copy of the greater part of the stellar parallax work is completed, and it will be printed by the University and circulated without avoidable loss of time. The parallaxes of the following thirteen stars have either been completed or are in progress :—α, β, γ *Cassiopeiæ*, α *Cephei*, γ and ϵ *Cygni*, α and β *Andromedæ*, α *Arietis*, α *Persei*, β *Ursæ Minoris*, β *Leonis*, and α *Coronæ*. It has been already stated in a communication to the Society that, owing to the method of referring the star whose parallax is sought to four comparison stars, wherever possible, the *relativity* of the term 'stellar parallax' becomes more and more apparent.

In addition to the above, an inquiry was undertaken for the Photographic Committee of the Royal Society, in order to ascertain the comparative values of two mirrors of fifteen inches aperture, and of the focal lengths of 80 and 120 inches respectively. The result was an evidence of the practical superiority of the longer focus, and of the great advantages which may be expected from the application of mirrors to photographic researches. A report of this investigation was presented to the Royal Society, and published in their *Proceedings* of May 1888.

Much time has been necessarily expended on the erection of the photo-telescope for the international charting. The work was completed only at Christmas last. The driving mechanism may be regarded as successful, and the exposure of a photographic plate for several hours continuously can now be effected without intolerable stress to the observer. Hitherto no opportunity has occurred for an exposure beyond two hours. The present photographic object-glass is to be regarded as experimental only, and a greatly improved instrument is awaited, which in course of time Sir Howard Grubb will, no doubt, succeed in providing.

By the great courtesy of Admiral Mouchez and MM. Henry, a negative photographic plate of the *Pleiades* has been taken expressly for this Observatory, with a five minutes' exposure, on an average night. The perfection of the star images is very striking. The field also is measurable to the extent of a square plate $2^\circ \times 2^\circ$. Long experience of the difficulties inherent in the production of an available photographic object-glass has much enhanced the appreciation of MM. Henry's successful work herein.

So far as the light only is concerned, the photographic effects of the mirror and of the object-glass are practically equal.

Independently of astronomical work there are also important duties connected with University instruction, and in other similar directions. These have very properly consumed much time, but it may be doubted whether, after all, this variety of work is not of practical service to the Observatory, even in an astronomical point of view.

Temple Observatory, Rugby.

The usual instruction to members of the School has been continued, and the interest shown by boys has appeared to be on the increase during the past year.

Mr. Seabroke has continued the measurement of the motion of stars in the line of sight with the spectroscope on the reflector, and a new larger spectroscope has lately been brought into use.

Mr. Percy Smith left the Observatory at midsummer, and Mr. H. P. Highton has succeeded him, and has been practising with the micrometer with a view to continue the measurement of double stars.

Stonyhurst College Observatory.

In the course of the year a Rowland grating, $3\frac{1}{4}$ inches by $1\frac{5}{8}$ inch, has been mounted by Mr. Hilger, and now stands in the spectroscopic room adjoining the equatorial dome. As the instrument is intended principally for photographing the solar spectrum and spot spectra, the object-glasses of the collimator and viewing telescopes, which are three inches in diameter, are made of quartz. The plate-holder is arranged for making four exposures on the same plate, and it can be adjusted at any angle to the incident rays, so as to secure an exact focus for the extreme rays of the photo-spectrum. When the viewing telescope is used its position can be read by two micrometers on a 15-inch circle to within $0''\cdot25$. A stone pillar has been erected in front of the S.W. window of the spectroscopic room to support the heliostat and the $5\frac{1}{2}$-inch object-glass of Alvan Clark, which are to be used in connection with the grating spectroscope. The badness of the sky has so far interfered very much with preliminary experiments, but the photo-spectra already obtained show clearly what excellent results the instrument is capable of producing.

The 8-inch equatorial has been used during the day for solar work, and during the night for observing comets, occultations of stars, and the phenomena of *Jupiter's* satellites. Spectroscopic observations of the eclipsed Moon were made on January 28, and the 8-inch, $5\frac{1}{2}$-inch, and 4-inch equatorials were all employed in watching stars occulted by the Moon during the same eclipse. Barnard's Comets *e* and *f*, Sawerthal's Comet, and the minor planet *Sappho* were observed and some positions taken.

Large drawings of the Sun have been made on 223 days, and the solar surface was carefully examined on 18 additional days. These drawings have all been measured, and the spotted areas deduced. Complete measures of the chromosphere and prominences were secured on 84 days, together with partial results on three other occasions; and observations of the inclination or

apparent drift of the chromosphere flames were made with a wide tangential slit on 13 days.

Papers on the lunar eclipse, the solar surface, Barnard's Comet, *Jupiter's* satellites and lunar occultations have appeared in the *Monthly Notices*, and several communications have been sent to the *British Journal of Photography*.

The Rev. C. Colin, S.J., after spending twelve months at this Observatory, left in November for Antananarivo, to take the direction of the Government Observatory.

Mr. Common's Observatory, Ealing.

The 5-foot reflector was practically completed last September, and is now ready for work. On the few occasions that the weather has permitted, some trial photographs have been obtained that show a very satisfactory advance on those taken in 1883 with the 3-foot. It is intended to devote this telescope to the direct photography of the more important nebulæ and to spectroscopic work on such objects as can be best observed with such an aperture.

The 6-inch achromatic is in good order.

The transit instrument has been dismounted, and the room in which it stood used for a battery-room for two batteries of E.P.S. cells, available for lighting or power in the Observatory.

In the making of the 5-foot mirror much work was done of an experimental character in order to acquire the art of working glass. Many kinds of grinding and polishing substances, both for tools and for grinding or polishing the surface, were tried, as well as different lubricants and methods of testing. From the experience thus gained a definite plan of working and testing curved surfaces has been arrived at that is very certain, a mirror of 30 inches diameter having been since figured in a comparatively short time.

In addition to the machine made for the 5-foot mirror, on which mirrors of smaller size can be figured, another machine has been erected for grinding and polishing mirrors under 30 inches, both curved and plane, with means for figuring mirrors of very short focus. It is intended to prepare some mirrors of about 20 inches diameter, with a view of finding the shortest focus that will work, as such mirrors might be of great use on nebulæ, comets, and the corona during eclipse.

The Earl of Crawford's Observatory, Dun Echt.

In continuation of the work of preceding years, the transit-circle has been used by Dr. L. Becker chiefly in the observation of nebulæ, its large aperture recommending it for that purpose. On the whole, the weather was so unfavourable that the months

January to June afforded but 18 available nights, and September to December 20 nights: in all, 277 places of nebulæ were secured. On one-third of the observing nights it was clear for less than two hours. Fortunately, an improvement in the weather in the autumn permitted the observation of Comet 1888 *e* in the meridian on ten nights. The accurate co-ordinates of a number of comparison stars were also determined.

The study of the low-sun spectrum with the Rowland grating was continued on the Barmekin of Echt, by Dr. Becker, from June 16 to the end of September. Fifteen hours of actual observation, spread over 25 sunrises or sunsets, yielded 5,872 measures of lines, chiefly between *b* and F, which were checked by 6,518 positions of lines in the spectrum of the Sun at a considerable height above the horizon. These latter were obtained on nine days. The whole of the observations made in 1887 have been reduced to wave-lengths, and the remaining computations are in an advanced stage.

The 15-inch equatorial was used by Dr. Copeland for spectroscopic observations of nebulæ and bright stars. A considerable part of these was made with the Grubb stellar spectroscope, the smallness of the dome restricting the use of the large instrument by Cooke to objects of medium altitudes. Special attention was bestowed on the study of typical objects such as *o Ceti*, *β Pegasi*, *α Orionis*, *Arcturus*, and the great nebula in *Andromeda*. Including two nights in January 1889, the spectrum of Comet 1888 *e* was also observed on seven occasions. A few close double stars were measured in the autumn, but the season was very unfavourable as to definition, there having been only one really fine night (that of September 22) out of fifteen that were tried.

The comets of the year were usually observed micrometrically only when recent places were required for the computation or amendment of orbits. Comet Sawerthal was observed seven times; that of Brooks once; Comet *e* (Barnard) twice; and Comet *f* (Barnard) once. Most of these observations were made by Dr. Becker. Fifteen circulars, all relating to comets, were distributed in the past year, the larger part containing elements and ephemerides computed at Dun Echt.

The daily meteorological readings and the firing of the time-gun at Greenwich noon on Saturdays have been continued as in former years.

Much labour has been again devoted to the revisal of the manuscript and reading the proofs of the library catalogue, which is now nearly finished. It will fill about 500 quarto pages.

In view of the transference of the instruments and library to the Royal Observatory at Edinburgh, a revised and classified inventory has been drawn up. The instruments will probably remain in use at Dun Echt until some progress has been made with the new observatory buildings at Edinburgh.

Mr. E. Crossley's Observatory, Bermerside, Halifax.

As in past years, the phenomena of the satellites of *Jupiter* and *Saturn*, lunar occultations, and the measurement of double stars have formed the principal work of the Observatory. About thirty observations of the satellites of *Saturn* have been sent to Mr. Marth. The 3-foot reflector has occupied much of our time. The dome and the mechanism for moving it are in excellent order, and arrangements are being made for controlling the driving clock by Sir Howard Grubb's method, and a check telescope for photographic work has just been attached to the telescope.

Wolsingham Observatory (Rev. T. E. Espin's).

The search for stars with remarkable spectra has been continued during the year. In all, sixty-five such stars have been encountered in the sweeps, while fourteen of the variable stars have been observed with the spectroscope, in one of which, R *Cygni*, the F line has been found bright. Thirty stars given by various authorities as red have been also spectroscopically observed. One new variable star, R *Canum* ($\alpha = 13^h\ 42^m\ 43^s$ $\delta = +40^\circ\ 15'\cdot 9$; 1855) has been discovered. The variation is from 7·3 to below 13. In December the instrument was removed to the new observatory at Tow Law. The new observatory has a dome 20 feet in diameter, and is situated nearly 1,000 feet above the sea.

Mr. Huggins's Observatory.

The alterations and repairs of instruments reported in 1888 were continued. It should be specially mentioned that, since a new driving screw by Sir Howard Grubb has replaced the old one, the periodic irregularity of the motion, which was so unfavourable for spectrum work, has disappeared; now the action of the driving clock leaves but little to be desired.

These alterations and repairs have interrupted work but little in the last year. No possible opportunities of observing which have occurred have been lost. Though the weather has been exceptionally unsuitable for the purpose, photographs of the spectra of several nebulæ and of other objects have been obtained; but further photographs are wanted to complete the special investigation in hand before it is desirable to publish the conclusions to which they seem to lead.

Rousdon Observatory, Devon (Mr. Peek's).

Observations of long-period variable stars have been regularly made during the past year with the $6\frac{4}{10}$-inch equatorial telescope, 163 nights having been available for this purpose. The complete light curve has as far as possible been observed in each case. A sidereal clock by Sir Howard Grubb has been erected in the transit room.

The Earl of Rosse's Observatory, Birr Castle.

During the past year the work of the Observatory, Birr Castle, has been in the direction of the preparation of past observations for publication rather than in undertaking new investigations at the telescope. The total eclipse of the Moon on January 28, 1888, was, however, observed for radiant heat under exceptionally favourable circumstances, and the results, which were published shortly in *Nature*, February 2, 1888, and are now nearly ready for the press in their extended and fully reduced form, go to confirm those of October 4, 1884.

A detailed sketch of the Milky Way has been completed by Dr. Boeddicker, and only waits to be copied for the lithographer.

A long series of sketches of the planet Jupiter are nearly ready for issue with the *Transactions* of the Royal Dublin Society.

Some attempts at photography have been made, and it is hoped that in a short time it may be possible to adapt the instruments so as more nearly to meet the requirements of this new branch of work.

Meteorological observations continue to be made for the Government office as heretofore.

Sir Henry Thompson's Observatory, Hurstside, West Molesey, Surrey.

The dome and equatorial of this Observatory were constructed by Messrs. Cooke in 1887, but, owing to difficulties in obtaining a good flint lens, and to difficulties of mounting, the instrument was not ready for regular use until May 1888.

The objective of the equatorial is of 12 inches clear aperture, the focal length being 15 feet 3 inches. The dome, 30 feet diameter, has a framework of iron, and is covered with waterproof papier-mâché, the shutter being of Cooke's well-known pattern, allowing a wide opening near the zenith.

The Observatory being intended mainly for spectroscopic observations, Mr. Hilger was instructed to make a solar spectroscope with a 2-inch Rowland grating (14,438 lines to the inch).

The collimator and observing telescope of the spectroscope he constructed have achromatic objectives 2 inches diameter and 15 inches focal length, the whole being mounted in a convenient and effective manner, combining great rigidity with extreme lightness, 19 lbs. being the total weight. The micrometer of the spectroscope has powers of 50, 25, and 10, and is capable of measuring positions accurately to $\frac{1}{10000}$ of an inch.

Mr. Hilgor also made a star spectroscope, which has been found very effective for observations of faint stars and of nebulæ.

Systematic observations of Sun spots and the widened lines in their spectra, and of the forms, sizes, positions, and frequencies of prominences, were commenced in May, and continued to the end of the year.

With the star spectroscope the bright lines in γ *Cassiopeiæ*, β *Lyræ*, P *Cygni*, R *Cygni*, and *Mira Ceti* were frequently examined and measured, and it is hoped that the results of these observations will be communicated to the Society at an early date. The spectra of the Great Nebulæ in *Orion* and *Andromeda*, and of the Ring Nebula in *Lyra*, were also examined: the results were recently communicated to the Society.

Comet Barnard (September 2, 1888) was observed on five occasions, spectroscopic observations being possible on three of these, viz. November 8, 13, and 27, 1888, the spectrum on each occasion showing three *excessively* faint bands and a rather bright continuous spectrum, the positions of the bands being 5640, 5169, 4742.

A room attached to the Observatory has been fitted as a spectroscopic laboratory, and another as a photographic dark-room.

Colonel Tomline's Observatory, Orwell Park.

The past year has not been favourable for the ordinary work of this Observatory. Only three months have had more than an average amount of clear weather, while the remainder fell generally much below it. Thus, although every opportunity was taken to observe Olbers' Comet from the beginning of the year up to March 21, when the watch was abandoned, only three observations could be secured. The results of the observations of the several comets of the year may be summarised in tabular form as follows:—

Comet.		No. of evenings on which observations were taken.	Limits of date within which observations were made.
Olbers'	V. 1887	3	From Jan. 8 to Feb. 10
(concluding part of a series of 24 observations).			
Sawerthal	I. 1888	24	From Apr. 3 to Aug. 10
Brooks	III. 1888	13	„ Aug. 29 „ Oct. 8
Barnard	*e* 1888	31	„ Sept. 11 „ Dec. 31
Barnard	*f* 1888	7	„ Nov. 13 „ Dec. 30

Faye's Comet also was searched for on three occasions under favourable conditions as regards atmosphere, but it was not seen, and would appear to have been too faint for an aperture of 10 inches at this apparition.

The reductions of the above observations are all in an advanced state; those of the two former comets have been completed and published in the *Monthly Notices* of the Society, vol. xlix. No. 2, and the remainder will be communicated in like manner on the conclusion of the series, which, however, may possibly extend to some time yet.

Of miscellaneous work it may be mentioned that preparations for observing the occultations of small stars during the total eclipse of the Moon on January 28 were made, but were rendered futile by cloudy weather.

Hong Kong Observatory.

No report was drawn up last year owing to circumstances connected with a change of government in Hong Kong. His Excellency the present Governor has decided that purely astronomical observations are not to be subsidised here in future, but the magnetic observations are to be continued. The final reduction of all the double-star observations made since 1874 at Markree (and also a few in Hong Kong) by the present director of this Observatory was finished in the course of last year, and the final calculation of the orbit of the first comet of 1824, from observations made in Australia, will be done here.

The electric time-ball was dropped as usual at 1 P.M. The rate of the standard clock (with zinc and steel compensation) has been investigated, and the necessity of another standard clock (with mercurial compensation) has been recognised, and an order is being sent to a maker in London.

Sir W. Thomson's automatic tide-gauge has been working continuously, and two years' trace is now available. The electric light has been used for illuminating the wires in the transit instrument, and telephones and microphones for hearing the beat of the clocks at a distance, and for other purposes, and electric testing apparatus are being acquired.

The local meteorological observations and researches have been continued at the Observatory and at the Peak. Reports from about forty stations in China and in Corea have been utilised as far as funds were available. Extracts have also been made from log-books of vessels visiting the harbour. The typhoons from the beginning of 1884 till the end of 1887 have been exhaustively investigated, and data for investigating those of 1888 have been collected. Daily weather-reports and storm-warnings have been issued since 1884; but although gales caused by typhoons are frequent in summer and autumn, there

has been no opportunity for signalling a typhoon about to rage in the colony since September 1884.

The fourth annual volume of observations was published last spring, but it had unavoidably to be made smaller than in previous years. A fifth volume will probably be published early next year. The "Instructions for making Meteorological Observations in China" and "The Law of Storms in the Eastern Seas" have been republished by the Chinese Government under the auspices of the Imperial Maritime Customs.

Natal Observatory, Durban.

During the past year the work of the Observatory has been partially suspended for the same reasons which restricted its work during the previous year; but during this period the astronomer has found it possible to make considerable additions to the buildings by the construction of additional rooms and a new laboratory. The present year, 1889, finds the Observatory once more restored to its normal position, though the observing staff is still restricted to the astronomer and one assistant.

The principal work in progress at the Observatory is the comparison of the declinations deduced from observations made at observatories in the northern and southern hemispheres, by a comparison by Talcott's method of the zenith distances of northern stars with southern circumpolars both above and below the pole. During the year a number of observations have been obtained.

Considerable progress has also been made in the observations of pairs of equi-zenith-distance stars for the determination of the latitude of the Observatory, which forms the second fundamental point of the South African Geodetic Triangulation.

During the year the Greenwich Lunar Observations for the ten years 1878–1887 have been reduced and compared with the theoretical basis of Hansen's Lunar Tables in the same manner as those for the sixteen years 1862–1877 are reduced, compared, and discussed in the memoir on the "Corrections required by Hansen's *Tables de la Lune*"—Memoirs, 1885. The result shows that the application of the corrections deduced from the observations for the sixteen years 1862–1877 brings the tables into close agreement with the observations for the subsequent ten years, 1878–1887. The results of the discussion of these observations are being drafted for publication.

The observations of the lunar crater Murchison A, made by Mr. Campbell at the Arkley Observatory during the three years 1882–1884, have been reduced and compared with similar observations made at the Natal Observatory during the three years 1883–1885. The theoretical discussion of these observa-

tions with the similar ones made by Mr. Campbell at the Arkley Observatory during the years 1879–1881 is now in progress with the view of deducing values for the parallactic inequality, and the coefficients of the real libration in longitude and latitude, which shall be independent of the assumed value of the semi-diameter of the Moon.

Slow progress is being made with the researches on the lunar theory. The fundamental basis for the determination of the coefficients of the inequalities due to the disturbing action of the planet is complete, and only requires reduction to the ordinary form of expansion and to numbers. It is hoped that both time and health will be found during the coming year to effect much more work on these investigations than was found possible during the last two years, when nearly the entire routine work of the Observatory fell on the astronomer. The reduction of the tidal observations for Natal has been completed during the year.

Mr. Tebbutt's Observatory, Windsor, New South Wales.

The work of this Observatory rests upon one observer, and considering that he has been enabled to obtain occasional assistance only in the reductions, it has been rather heavy during the past year. The errors of the 3-inch transit instrument have been remarkably steady throughout, and the rate of the standard sidereal chronometer fairly good. Nine hundred and eleven star transits have been observed and reduced for time. The extra-meridian work accomplished with the 4½ and 8-inch equatorials is as follows:—

Observations of the occultations of fifty-three stars by the Moon, comprising fifty-one disappearances at the dark and two at the bright limb, and three reappearances at the dark limb. Of the occulted stars forty have been identified and thirteen have had their places approximately determined.

Observations of the phenomena of *Jupiter's* satellites classified thus: Transit-ingress, I. 7, II. 5, III. 1. Transit-egress, I. 7, II. 6, III. 3. Occultation-disappearances, I. 7, II. 4. Occultation-reappearances, I. 2, II. 3, III. 1. Eclipse-disappearances, I. 5, II. 3, III. 5. Eclipse-reappearances, I. 7, II. 3, III. 6.

Observations of the occultations of *Venus* and *Saturn* by the Moon on March 9 and June 13 respectively.

Observations of both phases of the occultation of 47 *Libræ* by *Jupiter* on June 10.

230 filar-micrometer comparisons of *Jupiter* and *β' Scorpii*, on May 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25.

145 filar-micrometer comparisons of *Pallas* in high south declination on November 12, 13, 14, 15, 19, 20, 21, 26, December 1, 11, 14, 18, 19, 20, 21; and 10 square-bar comparisons on December 3.

Measures of 27 southern double-stars.

215 filar-micrometer comparisons of Comet *a* (Sawerthal), 1888, on the mornings of February 28, 29, March 3, 4, 5, 7, 8, 9, 10, 11, 12, 15, 16, 18, 19, 20, 22, 26, 29, 30, April 1, 2, 3.

63 square-bar comparisons of Encke's Comet on July 8, 10, 11, 15, 16, 18, 25, 26, 31, August 1.

157 square-bar comparisons of Barnard's Comet of September 2, 1888, on November 5, 10, 12, 13, 21, 22, 26, December 1, 2, 3, 4, 5, 23, 24, 25, 26. These observations have been carried into the current year. Faye's Comet was glimpsed with the 8-inch equatorial on December 3.

Determination of the magnitudes of μ *Argûs* and R *Carinæ*.

Sundry observations for determining instrumental constants.

In addition to the purely astronomical work, the usual 9^h A.M. meteorological observations have been made with great regularity.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets.

The following ten minor planets were discovered in the year 1888:—

No.	Name.	Date of Discovery, 1888.	Discoverer.	Place of Discovery.
272	Antonia	Feb. 4	Charlois	Nice
273	Atropos	Mar. 8	Palisa	Vienna
274	Philagoria	April 3	"	"
275	Sapientia	15	"	"
276	Adelheid	17	"	"
277	Elvira	May 3	Charlois	Nice
278	Paulina	16	Palisa	Vienna
279	Thule	Oct. 25	"	"
280	Philia	29	"	"
281	Lucretia	31	"	"

Minor planet No. 269, discovered by Herr Palisa on Sept. 21, 1887, has been named *Justitia.*

The Comets of 1888.

In 1888, four comets have been discovered, and two comets of short period have been observed at their return to perihelion.

Comet I., 1888.—Discovered by Mr. Sawerthal of the Cape of Good Hope Observatory, on February 18, at which time the comet was visible to the naked eye. The nucleus shone as a star of the 7th magnitude, and was accompanied by a tail 2° in length. The northerly motion was more than a degree a day, so that the comet, notwithstanding its considerable southern declination when discovered, soon became visible in this hemisphere, and was very continuously observed up to the middle of July. It was visible to the naked eye in this country from April 7 to May 14. A distinguishing feature in the history of this comet has been the sudden outburst of brilliancy

which occurred about May 20, when the appearance of the comet indicated a sudden increase of light some five or six times greater than that possessed on the days immediately preceding. The spectrum of the comet has shown, in addition to the three characteristic cometary bands, a faint but fairly broad continuous spectrum. The path is fairly represented by a parabolic orbit, but elliptic elements have been computed by Dr. Berberich, which give a period of 2,370 years.

Comet II., 1888.—A return of Encke's Comet, which appears to have been first seen by Mr. Tebbutt, of Windsor, N.S.W., on July 8. Observations of position did not commence at the Cape of Good Hope till August 3, on which day the ephemeris, computed from preliminary elements supplied by Dr. Backlund, of Pulkova, showed an error of 8 secs. in R.A., and 1′·3 in declination. The geocentric motion of the comet at the time was rapid, so that this error does not point to any considerable alteration in the mean anomaly, and it was conjectured that owing to neglected perturbations the uncertainty of the ephemeris might amount to 3′. The circumstances of the return were very unfavourable to observation, and these difficulties were increased by the figure and general appearance. The last reported observation is August 9.

Comet III., 1888.—On August 7, Mr. Brooks, of Geneva, N.Y., detected a faint telescopic comet, at which date it had already passed its perihelion, and the brilliancy was diminishing. It was followed, however, at various observatories till the beginning of October, the observations being well represented by a parabolic orbit: the best is, perhaps, that of Dr. Krueger, in *Ast. Nach.*, No. 2855. The elements do not resemble any hitherto computed.

Comet IV., 1888.—A return of the comet of Faye. Dr. Perrotin, of the Nice Observatory, fortunately secured an observation of this exceedingly faint comet on August 9, but the faintness of the comet and the unfavourable position in the sky have prevented it being generally observed. Though the last published elements represented the place of the comet in 1880–81 within an error of only $1^s{\cdot}5$ in R.A., and 9″ in declination, yet Dr. Axel Möller found great difficulties in representing the observations at that apparition, and those difficulties not being yet wholly overcome, no accurate ephemeris was published from the Lund Observatory. In the absence of an accurate ephemeris, Dr. Kreutz published sweeping positions to assist in its discovery, and the deviation from these positions showed the necessity of an alteration in the assumed time of perihelion passage of 2·6 days. Though the theoretical brilliancy of the comet slightly increased after August, the comet does not appear to have been re-observed till December 3, when it was again seen at Nice.

At the Lick Observatory, U.S., on September 2, Mr. Barnard discovered a small telescopic comet, the perihelion passage of

which does not occur till the end of January 1889, so that the comet will appear in the catalogues of that year. It was described as circular, one minute in diameter, with a well-defined nucleus of the eleventh magnitude, or fainter. The distinguishing feature of the elements is the very considerable perihelion distance (1·82 R), and owing to this fact and the position of the orbit, the theoretical brilliancy will diminish so slowly that for a whole year after the discovery, the comet may be expected to shine as brightly as it did when first seen.

Comet V., 1888.—Another discovery of the same astronomer on October 30, and in general appearance resembling the last-mentioned comet. The perihelion passage was passed early in September, but observations will be possible for some time to come. There is, however, no indication of deviation from parabolic motion.

Among the contributions to cometary literature during the year may be mentioned a monograph by Dr. H. Kreutz of the great September Comet 1882 II., and which, in conjunction with investigations at present being carried on by Professor Weiss, will form a complete discussion of the cometary systems of 1843 I., 1880 I., and 1882 II., all marked by small perihelion distance. The present monograph is distinguished by a very able discussion of the remarkable changes in the appearance of the nucleus, which proved so troublesome to the observer. This change of form introduced such difficulties that Dr. Kreutz has declined to use the observations made after March 9, 1883, in the formation of the normal places.

Another valuable contribution is that of Dr. Haerdtl on the motion of Winnecke's comet, undertaken primarily with a view to detect if possible any increase in the mean motion, similar to that exhibited by Encke's comet, and which is not sensible in Faye's, possibly owing to its great perihelion distance. The discussion shows, however, that there is absolutely no increase of the mean motion in the case of Winnecke's comet, and so far the "resisting medium" theory obtains no support. Perhaps the more valuable part of the paper is the determination of the mass of *Jupiter* from the perturbations of the comet, for which constant Dr. Haerdtl obtains the following value, $\frac{1}{1047{\cdot}152 \pm 0{\cdot}0136}$.

W. E. P.

The Corona in 1887.

Most of the results obtained on the occasion of the total solar eclipse of August 19, 1887, have now been published, and it is therefore possible to formulate some conclusions as to the shape of the corona. For this purpose the most important materials available are three photographs taken at Yomeiji-yama, Echigo, Japan (longitude 139° E.), by Sugiyama, prints and copies on glass of

which have been received by the Society; and drawings from photographs taken in Russia, viz. at Petrovsk (longitude 39° E.), by Glasenapp, published in a Russian pamphlet; and at Jurjewetz (longitude 43° E.), by Bélopolsky, published in the *Annales de l'Observatoire de Moscou.* Of these drawings one in each set is distinctly better than the others, which are often faulty; in what follows, therefore, the remaining drawings will not be considered.

On careful comparison, these two are found to be in very satisfactory agreement, and we may therefore take them to correctly represent the corona as seen in Russia at $18^{d}\ 16^{h}\ 20^{m}$ G.M.T. The excellence of the Japanese photographs and their accordance *inter se* leave little doubt that they are an equally good picture of the corona as seen in Japan at $18^{d}\ 18^{h}\ 25^{m}$ G.M.T.

We have here, therefore, an opportunity of looking for changes in the corona in an interval of two hours. And from the evidence available there would appear to have been a well-marked change in one of the streamers. There are three streamers—roughly speaking, at the S., S.E., and E. of the Sun—separated by well-defined gaps. But in the Russian corona the southern gap is distinctly larger than the eastern, while in the Japanese the reverse is the case; so that the general mass of the south-eastern streamer appears to have moved southward in the interval. There are two reasons for considering that this change is real:—

(1) For the remainder of the corona, the accordance is remarkably good.

(2) The estimation of the position of the south-eastern streamer is made comparatively easy by the existence of the other two. It is difficult to believe that a mistake should be made in estimating which of two adjacent and similar gaps is the larger.

Dr. G. W. Hill's Determination of the Mass of Titan from the perturbations which it produces in the motion of Hyperion.

By means of his own observations of *Saturn's* outer satellite *Hyperion*, made during the oppositions from 1875 to 1883, combined with Mr. Lassell's observations of 1852, Professor Asaph Hall showed that the peri-Saturnium of *Hyperion's* orbit had an annual *retrograde* motion of nearly 20° (*Monthly Notices*, R.A.S., vol. xliv. p. 363).

At first sight this result appeared to be inconsistent with the law of gravitation, since in the case of a body moving in an eccentric orbit, and disturbed by another moving in a nearly circular one, the secular motion of the peri-centre given by the ordinary theory will always be *direct.*

The observations had shown, however, that the mean motion of *Hyperion* and that of *Titan*, which is the body which principally disturbs it, are nearly commensurable with each other, three times the period of *Hyperion* being nearly equal to four times the period of *Titan*; and in an able paper entitled "On the Motion of *Hyperion*: a New Case in Celestial Mechanics," published in 1884, Professor Newcomb showed that on account of this near approach to commensurability certain terms in the expression for the rate of motion of the peri-centre, which would otherwise be insensible, assume, on the contrary, a predominating influence. This important paper of Professor Newcomb has been already noticed in the Annual Report of the Council for 1885, but the following additional observations upon it may not be out of place here, especially as they may tend to make more intelligible the subsequent remarks upon Dr. Hill's treatment of the same problem.

If l and l' denote the mean longitudes of *Titan* and *Hyperion* at any time, n and n' their mean motions, and ϖ' the longitude of the peri-Saturnium of the latter body at the same time, then the observations of Professor Hall show that the mean motion of ϖ' is nearly equal to $4n'-3n$, and that if a year be taken as the unit of time the value of each of these quantities is nearly $-20°$. Now with the same unit of time the value of n is $8246°$ nearly, while that of n' is nearly $6180°$, so that $4n'-3n$ is a very small quantity compared with n or n'; and Professor Newcomb's analysis shows that if both $4n'-3n$ and $\frac{d\varpi'}{dt}$ be very small quantities compared with n and n', and be also quantities nearly equal to each other, then the effect of the perturbing action of *Titan* upon *Hyperion* will be to make the mean value of $\frac{d\varpi'}{dt}$ to coincide with that of $4n'-3n$.

Hence if $V'=4l'-3l-\varpi'$, it follows that the angle V' will oscillate about a mean value, which the analysis proves to be $180°$.

From this it at once follows that *Hyperion* and *Titan* come into conjunction with each other only at or near the apo-Saturnium of the former satellite.

It should be remarked that an analogous proposition may be enunciated respecting the effects of the mutual action of the 1st and 2nd satellites of *Jupiter*, and also those of the mutual action of the 2nd and 3rd satellites of the same planet; only in both these cases the mean motions are nearly in the ratio of 2 to 1, instead of in that of 4 to 3.

A popular explanation of the way in which these perturbations are produced in the case of *Jupiter's* satellites is given in Section VI. of Sir George Airy's valuable work entitled "Gravitation," and in Art. (133) of that section the author remarks that "the same thing exactly would hold if the periodic

times were very nearly in the ratio of 2 : 3, or of 3 : 4, &c., but these suppositions do not apply to *Jupiter's* satellites." The ratio of 3 to 4 last named is the very one which obtains in the case of *Hyperion* and *Titan*.

Although there can be no doubt of the correctness of the general conclusions at which Professor Newcomb arrives in the memoir above referred to, it must be confessed that the numerical results which he obtains leave much to be desired. The method employed is the ordinary one in which the disturbing forces are developed in series proceeding according to powers of the ratio $\left(\frac{a}{a'}\right)$ of the semiaxes of the orbits of the disturbed and disturbing bodies. In the case of *Hyperion* and *Titan* this ratio is nearly 0·825, and consequently the convergence of the series employed is very slow, and a very large number of terms must be taken into account in order to obtain a good degree of approximation. A still more serious objection to the ordinary method of integrating the differential equations which proceeds by first neglecting the disturbing forces altogether, and then gradually takes into account the 1st, 2nd, and higher powers of the disturbing force, is that when the mean motions of the bodies are nearly commensurable, some of the divisors which occur in the integrations may be of the same order of smallness as the disturbing force itself, and thus terms which involve the first power of the disturbing force may after integration lead to others which are independent of the disturbing force. This would indicate that in such a case the ordinary form of solution would require to be changed, and that the arbitrary constants required to complete the solution would enter it in a different form in this special case from that in which they appear in the more general and usual case.

For example, if n and n' represent the mean motions of two satellites which disturb each other, n and n' in the general case are two independent arbitrary constants; but in the special case of *Hyperion* and *Titan*, n and n' are *not* independent of each other, but are connected by a relation of the form $4n' - 3n =$ a small constant depending on the mass of *Titan*, and the deficient arbitrary constant is replaced by another which determines the amount of the libration in the motion of the peri-Saturnium of *Hyperion*.

The same problem has been treated in a different way by M. Tisserand, and more fully by Professor Ormond Stone; but the numerical results which have been obtained by these mathematicians are unsatisfactory, owing to the slow convergence of the series employed to represent the co-ordinates of *Hyperion*, and the consequent necessity of taking into account a much greater number of terms than they have done.

In two papers, one of which appeared in June 1887, in Professor Ormond Stone's *Annals of Mathematics*, and the other in Dr. Gould's *Astronomical Journal* for July 12, 1888, Dr. G. W. Hill has attacked this difficult problem in an entirely

different way. He begins by discussing the particular case in which the inequalities of the longitudes and the radii vectores are all functions of the mean elongation of the two satellites from each other, so that when the satellites are in conjunction or opposition they are moving perpendicularly to their radii vectores. He assumes the mass of *Hyperion* to be so small that it may be altogether neglected, so that the motion of *Titan* may be considered to be purely elliptical, and in order to simplify the problem still more he assumes that the orbit is circular. By dividing any interval of time into a great number of small intervals the well-known method of mechanical quadratures enables us to find the co-ordinates of a body which starts from a given point with a given velocity and in a given direction, and is acted on by known forces, without its being necessary to integrate the equations of motion.

This process is attended with the advantage that no powers of the disturbing force are neglected.

Professor Hall's observations give us the average daily motion of *Hyperion* and its radius vector when in opposition to *Titan* compared with the radius of *Titan's* orbit, supposed circular. The mean daily motion of *Titan* is well known from Bessel's observations. Hence it is found that the interval between opposition and conjunction, or half the synodic period of the two satellites, is $31^{d}\cdot818$, and that the motion of the line of conjunction in this interval, which by what has been remarked before is equal to the motion of the line of apsides of *Hyperion* in the same time, is $-1^{\circ}\cdot638$.

In order to trace the path of *Hyperion* from opposition to conjunction by mechanical quadratures, two quantities, which are at first unknown, require to be determined, viz. (1) the velocity with which *Hyperion* starts from opposition, and (2) the mass of *Titan*. These are to be determined by the two conditions that (1) *Hyperion* must arrive at conjunction with *Titan* after the lapse of 31,818 days, and (2) that it must at that time be moving at right angles to its radius vector.

The values of these two unknowns must be at first assumed, and then corrected by making repeated trials until the required conditions are fulfilled.

An approximate value of the velocity of *Hyperion* when in opposition may be found from the elliptic elements of its orbit, which are approximately known from the observations; but the mass of *Titan* is at first supposed to be entirely unknown, and in order to find a first approximate value of this mass to be employed in the definitive calculations, Dr. Hill computed the motion of the line of apsides during the half synodic period from opposition to conjunction, neglecting all but the first power of the disturbing force, so that this motion is proportional to the assumed mass of *Titan*.

The first approximate value of the mass of *Titan* thus found is $\frac{1}{4468}$, the mass of *Saturn* being taken as unity.

The mass of *Titan* finally resulting from Dr. Hill's calculations is $\frac{1}{4714}$, and the osculating elements of *Hyperion* at opposition are:—

Mean daily motion = 60963″;

Mean distance from *Saturn* = 1·2088, the radius of *Titan's* circular orbit being unity;

and the eccentricity of the orbit = 0·09947.

Dr. Hill gives a table which shows the difference between the mean and true longitude of *Hyperion*, and the value of the radius vector, corresponding to the argument days after, or days yet to elapse before, opposition with *Titan*. J. C. A.

M. Tisserand's "Traité de Mécanique Céleste."

Mons. F. Tisserand has very recently brought out an elegant volume, forming the first part of an extensive treatise on the *Mécanique Céleste*. This valuable work is founded on the lectures which the author has given at the Sorbonne since 1883, first as the deputy and afterwards as the successor of Mons. Puiseux.

The first volume is devoted to the general theory of perturbations, founded on the method of the variation of the arbitrary constants. The application of this method to the mechanics of the heavens is presented in two different forms, having reference to the labours of Jacobi and to those of Lagrange respectively. The theory of the method is one of great simplicity, though, perhaps, it does not always supply the most rapid means of actually calculating the perturbations. The author has thought it well to adopt the same formulæ and notation as those which have been employed by Le Verrier in developing the theories of the ancient planets, which have been published in the *Annales de l'Observatoire*, so that the present volume may be regarded as forming a very complete introduction to this work of Le Verrier.

In one chapter the author presents, in a succinct form, a theory of the functions of Bessel, and in another an investigation of Hansen's elegant formulæ for the development of certain functions of the co-ordinates in the case of elliptic motion.

A separate chapter is devoted to the subject of the discovery of *Neptune*.

In order to render his treatment of the theory of perturbations more complete, the author has added some interesting chapters treating respectively of Poisson's theorem respecting the invariability of the major axes of the planetary orbits, of Gauss's remarkable method of calculating the secular inequalities, and of Hansen's transformation of the differential equations, applied with so much success by him in determining the perturbations of the minor planets.

As might be expected, the greatest attention to elegance is shown throughout in the exhibition of the mathematical formulæ, and the attractiveness of the work is much enhanced by the beauty of its typographical execution. J. C. A.

Professor Oppolzer's Researches on the Lunar Theory.

In the 54th volume of the *Denkschriften* of the Imperial Academy of Sciences of Vienna there is published a very elaborate paper, entitled "Zum Entwurf einer Mondtheorie gehörenden Entwicklung der Differential-quotienten," by the late Professor von Oppolzer, and completed after his death by Dr. Robert Schram. A very full sketch of Professor Oppolzer's new method of treating the Lunar Theory is given by him in the 51st volume of the *Denkschriften.* In this method the Sun and Moon are referred to a system of moving rectangular axes, the axes of x and y at any time being in what may be called the plane of the Moon's mean orbit at that time, and that of z perpendicular to that plane. He then introduces what he calls "proportional co-ordinates" which are respectively equal to the real co-ordinates, each multiplied by a variable quantity $1+\gamma$.

Following the example of Hansen, Professor Oppolzer introduces a disturbed time ζ, and a corresponding disturbed mean anomaly, and the two proportional co-ordinates x_0, y_0 are treated as undisturbed co-ordinates which belong to the time ζ.

The determination of ζ, γ, and of the disturbed mean anomaly at any time is made to depend on the integration of certain differential equations involving functions of the co-ordinates which Professor Oppolzer denotes by I, II, III, IV′, and V′, and these integrations can only be performed by means of repeated approximations, first employing the undisturbed values of the functions which enter into them, and then repeating the process with more and more approximate values as they are successively determined.

In the paper now under notice, the first part of Professor Oppolzer's plan of operations is completed, viz. the development of the differential quotients $\frac{d\mathrm{I}}{dt}$, $\frac{d\mathrm{II}}{dt}$, &c., to the 8th order of small quantities, taking into account only the undisturbed values of the co-ordinates. The developments are purely analytical, and appear to have been carried out with the greatest care, all the calculations having been made independently by three computers.

The results are exhibited in tables which are very clearly arranged, so as to admit of very ready examination. J. C. A.

Professor Oppolzer's "Canon der Finsternisse."

A very important astronomical work is the *Canon der Finsternisse* of the late Professor Oppolzer, published as vol. lvii. of the *Denkschriften* of the Mathematical and Natural History Class of the Vienna Academy. It contains data for computing the circumstances of 8,000 solar eclipses between 1207 B.C. and A.D. 2161; and in the case of those which are total or annular, the first and last points of the Earth where the totality occurs, and the place where it occurs at noon, are given to the nearest degree of latitude and longitude. This information is rendered more available to the student of history by a series of 160 charts, which show approximately the position of the central lines for all such eclipses when they lie between the North Pole and 30° south. Further, for 5,000 lunar eclipses between nearly the same dates, there are data from which the time and magnitude of the greatest eclipse and the duration of both partial and total eclipses can be seen; and also, by the use of a table in the preface, one can easily determine whether any given eclipse has been or will be visible at any place whose latitude does not exceed ±50°. Of course the central line of solar eclipses is but roughly given on the charts, but the formulæ by which a more accurate determination of the course can be made are given fully and conveniently. Hitherto, for ancient eclipses we have only had the list by Pingré in *L'Art de vérifier les Dates*, a work which, meritorious as it was for its date, is so imperfect that it cannot be relied on. This "Canon" of Oppolzer's now entirely replaces it, and offers by its charts far greater convenience to the inquirer. It may not, then, be out of place to give some information as to the foundation of the computations.

Starting with Hansen's Tables of the Moon and Le Verrier's of the Sun, and comparing them with ancient solar eclipses, Professor Oppolzer found empirical corrections, which he ultimately reduced to the form of corrections to the time of conjunction, the longitude of the Moon, and her distance from the ascending node of her orbit. Applying these, he constructed Syzygy Tables (published by the Astronomische Gesellschaft in 1881), which give the means of readily computing the time of any full or new moon, and the elements for all solar eclipses.* In these tables, of course, all the equations with small coefficients are omitted. Tables for computing the lunar eclipses were published in vol. xlvii. of the Vienna *Denkschriften*; and, finally, these two sets of tables have been utilised in the volume which is the subject of this notice, and the result placed in a most convenient form before the student of eclipse lore.

* Professor Newcomb published Tables for Solar Eclipses in 1879, using his corrections to Hansen's Tables in forming them.

M. Lœwy's Method of Determining the Constant of Aberration.

The determination of the constant of aberration is one of the most complex problems in practical astronomy. The methods which have been adopted for its solution involve (if they are to be successful) the elimination of almost all the errors that can possibly affect an astronomical observation—an elimination which, it must be confessed, has hitherto only been partially achieved. Accidental errors of observation, accidental and systematic errors of instrumental constants, errors of the clock or of personal equation, as well as the uncertainty pertaining to the elements of reduction, especially to precession and nutation, of which an accurate knowledge is necessary in order to obtain the value of the constant of aberration to $0''\cdot01$ or $0''\cdot02$—all these sources of error have to be taken into account, and, if possible, their influence eliminated from the result. Nyrén has, in fact, put on record his opinion that none of the methods hitherto adopted have furnished a result free from systematic error. Under these circumstances it is a distinct advance to be able to determine the value of this fundamental constant from differential measures alone, thus avoiding the most serious of the difficulties which beset the investigator who proceeds along the old lines. This M. Lœwy enables us to do by proceeding according to the method which he explains, and the details of which he elaborates, in his collection of papers reprinted from the *Comptes Rendus de l'Académie*, tomes civ. et cv., entitled "Nouvelles Méthodes pour la Détermination de la Constante de l'Aberration." The principle of the new method is based on the observation of the distance of two stars by the aid of a prism-shaped double mirror, placed in front of the object-glass of an equatorial, by means of the two reflecting surfaces of which the images of two stars, situated in different parts of the sky, appear side by side in the field of the telescope, and their angular distance, in a known direction, can then be measured with a micrometer. To obtain the aberration it is, of course, necessary to observe the pairs of stars at successive epochs, and the results are compared in accordance with the theory of the subject which M. Lœwy has worked out. The first observation is made when the stars are at an equal altitude, above the horizon, and the second, after the prescribed interval, under the same circumstances. The difference of the measures gives a multiple value of the aberration free from instrumental errors and errors of refraction, and also free from errors arising from the use of erroneous values of precession, or nutation, or proper motions of the stars. In fact, with a double mirror of 45° angle, an interval of three months (thus avoiding observation during the daytime) is sufficient to give, for zodiacal stars, a variation in distance equal to twice the value of the constant of aberration,

whilst in the ordinary method the *maximum* difference is no more than this: aberration affecting the distance of two stars much more considerably than it does the co-ordinates of each.

M. Lœwy has worked out the details of his method both on the practical and theoretical side, and there is now nothing wanting to complete his work except an actual determination of the constant of aberration by the new method. This, from the completeness in detail of M. Lœwy's memoir, any one who has the requisite means and skill can do without much difficulty. We hope, however, that M. Lœwy himself will continue to give his attention to the subject (we understand that he is now engaged in the selection of suitable pairs of stars and other preliminary work), and will not rest from his labours until he has added to the great service which he has rendered to our science the achievement of a successful determination of this important astronomical constant. A. M. W. D.

Herr L. Struve's Determination of the Value of the Constant of Precession and of the Proper Motion of the Solar System.

An important paper has recently been published by Herr Ludwig Struve in the *Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg*, vii^e série, tome xxxv., No. 3, with the title, "Bestimmung der Constante der Präcession und der eigenen Bewegung des Sonnensystems." Herr Struve takes as the basis of his investigation the proper motions of more than 2,500 stars, deduced from the comparison of their positions for 1755, as given in Auwers' new reduction of Bradley's observations, with their positions for 1855, as given in the Pulkowa Catalogue of 3,542 stars for that epoch, and (for the fundamental stars) the two catalogues of Pulkowa fundamental stars for the epochs 1845 and 1865, from the mean of which the positions of the catalogue of 3,542 stars for 1855 have been deduced. In bringing up the star places from 1755 to 1855, O. Struve's constant of precession has been used. Feeling the force of Airy's objection to the method usually followed in investigating the direction of the solar motion, i.e. assuming the direction to be known, and determining a correction to it, Herr L. Struve has used Airy's formulæ in his researches, so that a correction to O. Struve's constant of precession and a determination of the R.A. and declination of the apex of the solar motion, as well as of the velocity of the latter, is found from the stellar proper motions, with no other assumption than that of the relative distances of stars of different magnitudes. These are taken in accordance with W. Struve's numbers, and this assumption is, of course, the weak point in this (as in other) investigations on the motion of the Solar System.

Proceeding in this way, Herr Struve finds the value of the

luni-solar precession for 1805 to be $50''\cdot3514$; Bessel's and O. Struve's values (both of them also deduced from Bradley's observations) being respectively $50''\cdot3635$ and $50''\cdot3798$. Correcting O. Struve's value for error of equinox in the *Fundamenta* and in the Dorpat observations, the difference between it and the present determination is reduced from $0''\cdot0284$ to $0''\cdot0147$, which is no greater than might be expected, considering that the mean error of O. Struve's determination, which depends on 392 stars only, is $\pm0''\cdot0112$.

The co-ordinates of the point towards which the Solar System is moving are, from this discussion, $A = 273^\circ\cdot3$, $D = +27^\circ\cdot3$. From a consideration of the results which have been obtained by former investigators, Herr Struve concludes that the direction of the solar motion may now be considered known within not very wide limits, but that the variation in this direction, depending on the time, is still unknown. Combining the most trustworthy results for the co-ordinates of this point, we have $A = 266^\circ\cdot7$ and $D = +31^\circ\cdot0$. With regard to the velocity of motion of the Solar System some very discordant results have been obtained. The present discussion gives for the motion of the Solar System in 100 years, in a direction at right angles to the line of sight, as seen from a star of the sixth magnitude, the quantity $4''\cdot36$. O. Struve and Dunkin found for the same quantity the values $4''\cdot31$ and $5''\cdot22$ respectively. The mean of the three determinations is, therefore, $4''\cdot63$. Other astronomers, however, who have attacked this question in different ways have found very different results, and too much reliance must not be placed on the value given above, which is deduced from accordant, but not altogether independent, separate determinations.

Herr Struve's results depend on a larger number of stars than have hitherto been used by any investigator in researches on these subjects, and astronomers will appreciate the laborious zeal with which he has discussed the proper motions of such a large number of stars, and will hail with satisfaction the appearance of another determination of a fundamental astronomical constant from the Pulkowa Observatory, which has already done so much for the advancement of practical astronomy. A. M. W. D.

Mr. Lockyer's Meteoric Hypothesis.

During the past year Mr. Lockyer has continued his researches on the spectra of meteorites in connection with the spectra of the heavenly bodies. The outcome of some of his inquiries formed the subject of the Bakerian Lecture at the Royal Society last April, under the title of "Suggestions on the Classification of the Heavenly Bodies." His wide induction as to the meteoritic constitution of the universe, to which reference was made in last year's report, was there extended, and various

tests as to the probable truth of the hypothesis applied. The general basis of the hypothesis is that all the bodies in the universe are or have been swarms of meteorites, the present differences between them depending upon differences of temperature (the heat being brought about by collisions due to gravity) and the differences in the distances apart of the constituent meteorites.

One of the tests applied to the general hypothesis was that of the forms of nebulæ, and Mr. Lockyer has demonstrated that globular and spherical nebulæ, which have never been satisfactorily explained before, may be well explained by regarding them as collision shells in a swarm in which the meteorites revolve in orbits round a common centre of gravity. Further, cometic nebulæ can also be explained on the supposition that a very condensed swarm is moving at a high velocity through a sheet of meteorites at rest, or the swarm may be at rest and be surrounded by a moving sheet; the disturbance set up would thus gradually spread out like a fan behind the nucleus.

The main part of the paper, however, dealt with the classification of stars. Mr. Lockyer pointed out that, although nebulæ and comets have hitherto been regarded as things quite distinct from stars, this distinction no longer holds. Further, it is shown that all previous classifications of stars, which are based on the assumption that all stars are in a state of cooling, must give way if there be a line of increasing as well as a line of decreasing temperature; that is, if some stars are getting hotter while others are getting cooler. It having been demonstrated that the old Class III*a* stars are meteor-swarms which will ultimately develop into the *α Lyræ* type by the complete vaporisation of the constituent meteorites, and that the Class III*b* stars have run through all the other stages, it is clear that the III*a* stars and the III*b* stars cannot possibly represent either successive stages or different types of the development of any stage, as Vogel's classification supposes.

The new classification suggested is based on the existence of bodies which are increasing in temperature as well as of bodies which are decreasing in temperature.

The following is a statement of the new groupings:—

GROUP I. Radiation lines and flutings predominant. This group includes nebulæ, comets near aphelion, and the so-called "stars" with bright-line spectra.

GROUP II. Mixed carbon fluting radiation and metallic fluting absorption predominant. This group corresponds to the old Class III*a*, and includes some comets near perihelion.

GROUP III. Line absorption predominant, with increasing temperature. The more advanced species will be marked by greater simplicity of spectrum.

This group comprises *some* of the members of the old Class II*a*.

GROUP IV. Simplest line absorption (hydrogen) predominant. This group corresponds to Class I., and includes only the very hottest stars.

GROUP V. Line absorption predominant, with decreasing temperature. Those stars of Class II*a* which do not fall in Group III. will fall in this group.

GROUP VI. Carbon absorption predominant. This group corresponds to the old Class III*b*, of which 152 Schj. is the type.

GROUP VII. Dark or nearly dark planetary bodies.

It will be seen that in this new classification there are several fundamental departures from previous ones, chiefly as regards the separation of the III*a* and the III*b* stars, and the separation of the bright-line stars from stars of the *a Lyræ* type. It also includes nebulæ, and comets in their various stages, which the older classifications do not take into account at all.

Another very important difference lies in the division of the old Class II*a* stars into two groups, one representing increasing and the other decreasing temperatures. On the ascending side of the temperature curve the varying volatilities of meteoritic constituents brought out by successively higher temperatures are in question, whilst on the descending side of the curve the spectra will depend upon successive chemical combinations rendered possible by a gradual reduction of temperature in a gaseous mass.

The spectroscopic observations of the II*a* stars have hitherto been made on the supposition that all of them were cooling bodies, so that no effort has been made to establish the necessary criteria.

Mr. Lockyer has since succeeded in determining some of the spectroscopic criteria which will enable observers to assign any particular Class II*a* star to either Group III. or Group V., as the case may be, of his new classification.

As a test of the truth of the hypothesis, Mr. Lockyer shows how it bears the strain put upon it when it is used to indicate how the groups should be still further divided, and what specific differences may be expected. Thus, the first species of Group I. will include the least condensed swarms, and succeeding species will include the more condensed ones. The last species of all will consist of the hottest of the "stars" with bright lines, like *γ Cassiopeiæ*. In passing through this series, the spectroscopic differences observed between the different species are just what would be expected on the supposition that meteorites at gradually increasing temperatures are in question, and the general hypothesis is thus greatly strengthened.

It is also shown that if the next group (Group II.) be dis-

cussed in a similar manner the same conclusion is arrived at. The actual spectroscopic differences observed are exactly what they would be in a condensing swarm of meteorites with a gradually increasing temperature. The 297 stars of this group which have been observed by Dunér have been divided by Mr. Lockyer into fifteen well-defined species, the first beginning where the last of the preceding group leaves off.

The subject of variability, as far as it is associated with the stars which Mr. Lockyer considers to be uncondensed meteor-swarms, was also discussed at some length in the Bakerian Lecture. Mr. Lockyer's explanation of variability is closely allied to that of Newton, who ascribed the increase of brightness to the appulse of comets.

According to Mr. Lockyer, however, the variability in this class is produced in the simplest case by the revolution of a small meteor-swarm round a central one, the maximum occurring at periastrion. The greater the eccentricity of the orbit of the revolving swarm, the greater will be the difference between the luminosity at maximum and that at minimum. Variables of this group are, therefore, to be regarded as incipient double stars, the invisibility of the companion being due to its nearness to the primary, or to its faintness. The question of variability affords several tests of the general hypothesis. According to the hypothesis, stars of Group II. ought to be more subject to variability than the other groups, and, as is well known, this is the case. Variability ought also to be most common in the swarms with a mean condensation, for the reason that at first the meteorites are too sparse for many collisions to occur, and that finally the outliers of the central swarm are drawn within the orbit of the revolving swarm, so that there are very few additional collisions at periastrion. A discussion of the recorded observations has shown that this is the case, the greatest number of variables occurring in those swarms where spectroscopic observations indicate mean spacing. In cases where there is more than one maximum it is suggested that more than one revolving companion is concerned. This general view of variability, however, does not exclude other causes, such as eclipses by dark companions.

In a later paper, read at the Royal Society on January 10, 1889, Mr. Lockyer discussed the spectra of comets and the aurora, and the origin of binary stars, with the special object of testing the general hypothesis. The first part of the paper dealt with the spectra of comets. It being generally accepted that comets are meteor-swarms in the solar system which get brighter, and therefore hotter, as they approach the sun, if the hypothesis be true, the changes in their spectra ought to resemble those which take place in gradually condensing swarms outside the solar system. A detailed discussion of all the available spectroscopic observations of comets shows that this demand is satisfied by the facts. An important outcome of Mr. Lockyer's investi-

gations of cometary spectra is the unravelling of the spectroscopic phenomena produced by the integration of various simple spectra. The cause of the variation in the form of the citron band in cometary spectra, for example, has always been a difficult question, but Mr. Lockyer shows that such variations as are observed are not only explained but demanded by his hypothesis. Allowing for the differences in the conditions of observation, it is conclusively shown that the sequence of spectra is the same in comets as in condensing nebulæ. In both cases, when the number of collisions is just sufficient to render the swarms visible, *i.e.* in comets at aphelion and planetary nebulæ, the spectra are identical, consisting simply of magnesium radiation (λ 500). With the first increase of temperature continuous spectrum is added in both cases. As the nebulous swarm condenses, an apparent star, with a spectrum consisting of bright flutings and lines, is the result, and this is also the case in cometary swarms. Still further condensation of the nebulous swarm results in a body of Group II. giving mixed carbon radiation and metallic fluting absorption; and this, also, is a well-marked stage in the development of cometary spectra. Further condensation in both cases results in line absorption. Schiaparelli's view, therefore, that comets consist of nebulous materials drawn into the solar system by solar attraction, is now abundantly demonstrated by the spectroscopic study of nebulæ and comets. The discussion of cometary spectra, therefore, strengthens the general hypothesis, which would have been worthless had the cometary spectra been otherwise.

In the second part of this paper Mr. Lockyer proceeds to test his hypothesis by a discussion of the spectrum of the aurora. He points out that if in the aurora the solid particles of the meteorites, which are constantly entering our atmosphere, are acted upon by the electric current the spectroscopic phenomena observed ought to be similar to those observed in our laboratories when meteoric dust is subjected to electric discharges in vacuum tubes. It has never been possible to reconcile the aurora spectrum with any known spectrum of air, and some investigators have attempted to get over this difficulty by assuming that the aurora is produced under conditions of temperature and pressure which we are unable to imitate in our laboratories. A comparison of the aurora spectrum with the spectra of uncondensed meteor-swarms (γ *Cassiopeiæ*, &c.), however, indicates a very intimate relation between the two apparently different classes of phenomena.

The meteoric dust theory of the aurora, as first enunciated by Olmsted during the display of 1833, has practically been rejected, because the lines of iron were not seen in the aurora spectrum. But Mr. Lockyer's experiments show that the iron lines ought not to be seen except in auroræ of exceptionally high temperature.

The principal line in the aurora spectrum is shown to be in

all probability the remnant of the manganese fluting at λ 558. This fluting is found in every meteorite which has been spectroscopically examined at a low temperature, and, moreover, it is seen long before the iron with which it is associated in meteorites.

Even the small trace of manganese in the purest electrolytic iron is sufficient to render this fluting visible before the iron lines. The secondary lines seen in the aurora spectrum also appear to be due to constituents of meteorites which are most volatile at the lowest temperatures. The reason why the lowest temperature spectrum in nebulæ should be that of magnesium, while in the aurora it is manganese, Mr. Lockyer explains that in nebulæ heat due to collisions is in question, while in the aurora electrical conductivity as well as heat is in question. Magnesium, being mainly in combination with silica in the meteorites, would not be so likely to appear in electrical excitations as would the volatile metallic constituents.

There is, therefore, apparently strong evidence that the spectrum of the aurora is due to the presence of meteoric dust in the upper parts of the air, and the investigations strengthen the general meteoric hypothesis.

In the third part of the paper the hypothesis is further tested by a discussion of binary stars.

If the apparently single variables of the *Mira* type are really double nebulæ, as the hypothesis supposes, visible physical doubles are probably only further advanced stages, and by an investigation of the spectra of the components, or of their colours where spectra are not available, it ought to be possible to determine the stage of condensation of such double nebulæ. The main idea is that the component with the smallest mass will run through its changes at a greater rate than the other component.

According to the relative stages of development of the two components (or indirectly to their relative masses), Mr. Lockyer divides the known physical doubles into five classes.

There are really only three cases in which the components do not appear to have condensed from double nebulæ, and here the companions are probably additions of a cometary nature. The general view that the regular variables of Group II. are really double nebulæ is therefore strengthened by this investigation. The irregular variables of the group are regarded by Mr. Lockyer as multiple nebulæ, which will ultimately form multiple stars.

Throughout both papers, references are made to special laboratory researches on which most of the conclusions are based. In the case of the aurora, the meteoric theory is greatly strengthened by observations of an air vacuum-tube five feet in length, and by observations of the spectra of some of the manganese nodules dredged from the bed of the Atlantic by the "Challenger."

Professor G. H. Darwin on the Meteoric Theory of Cosmogony.

The publication of Mr. Lockyer's paper has led Professor George Darwin to make a suggestion for the reconciliation of two apparently divergent theories of the origin of planetary systems.*

He points out that the nebular hypothesis depends essentially on the idea that the primitive nebula is a rotating mass of fluid, which at successive epochs becomes unstable from excess of rotation, and sheds a ring from the equatorial region.

But, notwithstanding the high probability that some theory of the kind is true, the acceptance of the nebular hypothesis presents great difficulties. Amongst others it has been from time to time urged by various astronomers and physicists that the most probable origin of the planets was through a gradual accretion of meteoric matter, and the researches of Mr. Lockyer now afford actual evidence of the abundance of meteorites in space.

But the very essence of the nebular hypothesis is the conception of fluid pressure, since without it the idea of a figure of equilibrium becomes inapplicable. Now, at first sight, the meteoric condition of matter seems absolutely inconsistent with a fluid pressure exercised by one part of the system on another. We thus seem driven either to the absolute rejection of the nebular hypothesis, or to deny that the meteoric condition was the immediate antecedent of the Sun and planets.

Professor Darwin, however, maintains that by a certain interpretation of the meteoric theory we may obtain a reconciliation of these two orders of ideas, and may hold that the origin of stellar and planetary systems is meteoric, whilst retaining the conception of fluid pressure.

According to the kinetic theory of gases fluid pressure is the average result of the impacts of molecules. If we imagine the molecules magnified until of the size of meteorites, their impacts will still, on a coarser scale, give a quasi-fluid pressure. He suggests then that the fluid pressure essential to the nebular hypothesis is in fact the resultant of countless impacts of meteorites.

The problems of hydrodynamics could hardly be attacked with success if we were forced to start from the beginning and to consider the cannonade of molecules. But when once satisfied that the kinetic theory will give us a gas which, in a space containing some millions of molecules, obeys all the laws of an ideal non-molecular gas filling all space we may put the molecules out of sight and treat the gas as a plenum.

Laplace's hypothesis implies a plenum, subject to the laws of fluids, and Professor Darwin maintains that this plenum is merely the idealisation of the impacts of meteorites.

* *Phil. Trans. Roy. Soc.* vol. 180 (1889), *A*, pp. 1–69.

If a kinetic theory is to be applicable the colliding bodies must be highly elastic, and it is urged in the paper that when two meteorites meet with planetary velocity the sudden volatilisation of solid matter at their point of contact will act like an explosive, and that virtual elasticity will be thus imparted to meteorites in collision. The recondensation of gases generated in collision and the fusion of particles together will serve to counteract the fractures which must often occur.

But, if it be admitted that a kinetic theory of meteorites is thus far possible, yet the acceptance of the theory must depend on numerical values which can only be derived from the consideration of an actual system.

Professor Darwin accordingly imagines the sun to be broken up into a number of meteorites, which are distributed in a swarm extending beyond the orbit of the planet *Neptune*. These meteorites are supposed to be in motion, and to derive their velocities from their fall together from a condition of wide dispersion. If the kinetic theory be provisionally accepted, it is possible to calculate the arrangement of meteorites in space, for the density of distribution follows the same law as the density in a gaseous star in equilibrium under its own gravitation. This is a problem which has been considered by M. August Ritter in a series of papers contributed to the *Annalen der Physik* between the years 1878 and 1883, and many of his results are reinvestigated in this paper by different methods. When the mean velocity of the meteorites and their distribution have been found, it remains to compute the frequency of their collisions, and then to apply a criterion which shall determine whether the mechanical properties of the medium can be sufficiently like those of a fluid to allow of the truth of the nebular hypothesis.

These and other cognate problems are treated in the paper, and the principal conclusions arrived at may be summed up as follows:—

When two meteorites are in collision, they are virtually highly elastic, although ordinary elasticity must be nearly inoperative.

A swarm of meteorites is analogous with a gas, and the laws governing gases may be applied to the discussion of its mechanical properties. This is true of the swarm, from which the Sun was formed, when it extended beyond the orbit of the planet *Neptune*.

When the swarm was very widely dispersed the arrangement of density and of velocity of agitation of the meteorites was that of a gas under its own gravitation.

The actual mean velocity of the meteorites is determinable in a swarm of given mass, when expanded to a given extent.

The total energy of agitation in a spherical swarm is half the potential energy lost in the concentration from a condition of infinite dispersion.

The half of the potential energy lost, which does not re-

appear as kinetic energy of agitation, is expended in volatilising solid matter, and heating the gases produced on the impact of meteorites. The heat so generated is gradually lost by radiation.

The amount of heat generated per unit time and volume varies as the square of the quasi-hydrostatic pressure, and inversely as the mean velocity of agitation. The temperature of the gases volatilised probably varies by some law of the same nature.

The path of a meteorite is approximately straight, except when abruptly deflected by a collision with another. This ceases to be true at the outskirts of the swarm, where the collisions have become rare. The meteorites here describe orbits under gravity which are approximately elliptic, parabolic, and hyperbolic.

In this fringe to the swarm the distribution of density ceases to be that of a gas under gravity; and as we recede from the centre the density at first decreases more rapidly, and afterwards less rapidly than if the medium were a gas.

Throughout all the stages of its history there is a sort of evaporation by which the swarm very slowly loses in mass, but this loss is more or less counterbalanced by condensation. In the early stages the gain by condensation outbalances the loss by evaporation, they then equilibrate, and finally the evaporation may be greater than condensation.

Throughout the swarm the meteorites are to some extent sorted according to size; as we recede from the centre the number of small ones preponderates more and more, and thus the mean mass continually diminishes with increasing distance. The loss by evaporation falls principally on the small meteorites.

A meteor swarm is subject to gaseous viscosity, which is greater the more widely diffused is the swarm. In consequence of this a widely extended swarm, if in rotation, will revolve like a rigid body without relative motion (other than agitation) of its parts.

Later in the history the viscosity will probably not suffice to secure uniformity of rotation, and the central portion will revolve more rapidly than the outside.

The kinetic theory of meteorites may be held to present a fair approximation to the truth in the earlier stages of the evolution of the system. But later the majority of the meteors must have been absorbed by the central Sun and its attendant planets, and amongst the meteors which remain free the relative motion of agitation must have been largely diminished. These free meteorites—the dust and refuse of the system—probably move in clouds, but with so little remaining motion of agitation that (except perhaps near the perihelion of very eccentric orbits) it would scarcely be permissible to treat the cloud as in any respect possessing the mechanical properties of a gas.

Harvard Zone Observations made with the Transit Wedge Photometer.

Professor Pickering has recently published in vol. xiii., part 2, of the Annals of Harvard College Observatory an important catalogue of 4,143 stars of the 8th to the 14th magnitude in the zone $+0° 50'$ to $1° 0'$, the magnitudes being measured by a novel application of Professor Pritchard's wedge photometer. The transit wedge photometer consists of an ordinary wedge of tinted glass cemented to a glass plate carrying an opaque bar or heavy line parallel to the thinner end of the tinted wedge. This plate is placed in the focal plane of the telescope, and the bar is made coincident with an hour circle. The interval between the transit of a star across the bar and its disappearance in the wedge is the observed quantity from which the brightness of the star is to be deduced.

The particular wedge employed by Professor Pickering had the form of a square, the side of which was about 2·3 cm. in length, corresponding to $11'{\cdot}6$ in the field of the telescope. The bar over which the transits were observed was of tinfoil about 0·3 cm. from the edge of the wedge; three shorter bars were placed at right angles to the first, at intervals corresponding to $5'$ in the field of the telescope.

Upon the assumption that the light which traverses an absorbing medium is reduced in a constant ratio by its passage through a given quantity of the medium, the light of a star passing behind the wedge would vary in such a manner that equal intervals of time would correspond to equal differences of magnitude, if magnitude be expressed in the usual logarithmic scale. Upon this system the observations have been reduced. A careful discussion of the instrumental errors is given, and a determination of the constants. The method of observation was to record upon the chronograph the times at which the stars disappeared behind the bar parallel to the thin edge of the wedge, and their subsequent disappearances in the wedge itself, the observer calling out at the time an estimation of the declination of the stars in minutes and tenths, reckoning from the southern of the three bars forming the declination scale. By these means it was found possible to measure the brightness and approximate position of stars so faint as the 14th magnitude.

This work has been carried out in the complete and exhaustive manner that characterises so many of the researches at this Observatory, and the resulting catalogue forms a very interesting contribution to Photometric Astronomy.

Christiania Zones.

The Director of the Observatory of Christiania, Professor C. Fearnley, and Herr H. Geelmuyden, have published the zones between $+64° 50'$ and $+70° 10'$ undertaken for the Astronomische Gesellschaft. The first zone was observed February 17, 1870, the 310th and last, May 13, 1887. The observed places are reduced to 1875·0 in accordance with the general plan. This makes the fourth contribution to the series.

The Leyden Zones were published in 1875; the Helsingfors in 1883 and 1885; and the Kasan in 1886. The zones undertaken at Albany, N.Y., have long been concluded, but unfortunately no funds can be obtained for their publication—a very remarkable circumstance in the United States, where so much is given for the advancement of Astronomy.

Zone Catalogue of 4,050 Stars of the Cincinnati Observatory.

This publication contains the results reduced to 1885·0 of the zones observed with the 3-inch transit instrument during the years 1885, 1886, and 1887. The zone of the heavens included lies between 18° 50′ and 22° 20′ of south declination. Within these limits, it is stated, most of the stars down to the 8½ magnitude have been observed. The accuracy of the positions is not so great as the director could have wished; but for the purpose for which it is intended the catalogue is most valuable. 412 of the stars are found in the Argentine General Catalogue, and the comparison of the plans of the two catalogues shows small systematic variations in both R. A. and Declination, which was to be expected, as the zero stars used at Cincinnati all lie within the zone, and their places have been derived from various catalogues, not including that of the American Nautical Almanac (which is the basis of the Argentine General Catalogue), nor the Argentine General Catalogue itself.

Variable Stars.

This branch of Astronomy has received great impetus in the last few years. At present the Director of the Harvard Observatory is engaged upon an Index of all known observations of variable stars, published and unpublished. Catalogues of variables have been published (1) by Mr. Chandler of Harvard, in Gould's *Astronomical Journal*, viii., 81; and (2) by Mr. Gore, in the *Proc. Roy. Irish Academy*. Two new variables were discovered during the past year by Mr. Espin of Wolsingham. Professor Safarik announces in the *Ast. Nach.*, No. 2874, the discovery by

himself of no less than 17 new variables. The number of observers engaged in systematic observations of variables is now quite large.

Schiaparelli's Observations of Double Stars.

The distinguished Director of the Royal Observatory of Milan has published the measures of 465 double stars made with the Merz 8-inch refractor in the decade 1875–1885.

The catalogue is divided into four parts: the first part, by far the largest, is devoted to objects in the Dorpat Catalogue; the second to objects in the Poulkova Catalogue; the third to Mr. Burnham's double stars; the fourth to miscellaneous objects. The total number of observations is very large.

The catalogues which embody the results of the observations are preceded by an introduction of great importance, describing the instrument and micrometer, investigating the accidental and systematic errors, giving comparisons with Dembowski, and special notes; the whole forming a work of the highest importance in this branch of Astronomy.

Astronomical Photography.

The actual work of photographing the heavens, as agreed at the Astrophotographic Congress held in Paris in 1887, cannot be begun till the whole of the instruments are ready and the definitive plan of work settled. It is intended to hold a meeting of the Permanent Committee in 1890 for this definitive settlement of the working programme; by that time it is contemplated that all the instruments will have been erected and enough photographs taken to enable this programme to be settled.

Application has been made by the National Observatory of the United States to Congress for the necessary funds to provide instruments &c. to enable it to join in the work, and it is probable that one or two more observatories in America may also join.

The Permanent Committee of the Astrophotographic Congress has been most actively employed in discussing the various matters relating to the making of the chart of the heavens by photography, and has already published two parts of the "Bulletin," containing in the first number, memoirs on the mounting and orientation of the plates, by Dr. Gill; on the application of photography to the micrometric measurement of stars, by M. Thiele; on the influence of exposure on the position of the image, by M. Scheiner; and some correspondence, with a list of the observatories, numbering thirteen, that had up to that date joined in the work.

In the second part Dr. Vogel gives a communication on the

construction of the "reseaux de repère" and the deformation of the sensitive film. Professor Kapteyn contributes a memoir on the parallactic measurement of the plates, and there are other interesting letters and papers, including a brief but important note by MM. Henry, on the extent of the field of the negatives they have taken at the Paris Observatory. They think that a circular field of 3° might be counted on. This would correspond roughly to a square field 2° on the side; but even at 2° from the centre the images are fair—as the distance increases from the centre the images become regularly elliptical; at 1° 30′ from the centre the length of this ellipse is about $\frac{1}{250}$th of an inch. This result is practically what was known at the time of the Congress.

Means have been provided by our own Government for the establishment of photographic telescopes at Greenwich and at the Cape of Good Hope. There is almost a certainty that two or more instruments will be provided—but even with those already assisting, the number is sufficient to ensure the completion of the whole of the work agreed to be done.

Many of the instruments are in a forward state, and it will soon be possible to undertake the experiments that will be needed before the definitive plan already mentioned is settled.

It will be remembered that the Astrophotographic Congress passed the following resolution:—"The Congress deems it necessary that there should be a special committee devoted to other branches of astronomical photography than those relating to the chart, considering their importance and the relation which it is expedient to establish between these branches of research. This committee should place itself in communication with the committee of the chart. The Congress expresses the hope that MM. Common and Janssen would undertake the fulfilment of this wish."

MM. Common and Janssen met in London last September and in furtherance of the wish of the Congress sent the following circular letter to all those who were likely to be interested in this work:—

"In accordance with the wish expressed by the Astrophotographic Congress held at Paris last year, we are now occupied with the constitution of a committee to study the best methods of working, and to collect results obtained in celestial photography other than the photographic chart of the heavens (which is in the hands of the committee of the Congress). If you wish to take part in this work we should be glad if you would send to either of us your adhesion. Next year, when scientific congresses will be held in Paris, we intend to call together those who have thus expressed their adhesion in order to constitute a committee and examine the questions that we shall have to consider; we further ask you to let us know if you would be disposed to take part in this meeting at Paris at a time to be hereafter notified."

From English-speaking astronomers and observers the replies to this circular have been numerous and satisfactory.

The great equatorial of the Lick Observatory on Mount Hamilton has an extra glass which when placed in front of the ordinary object-glass enables the whole combination to be used as a photographic telescope—some photographs of the Moon thus taken have been sent over to this country by Professor Holden, the director of the Observatory, and they are surprisingly good. Photographs of other objects by this instrument will be looked for with interest.

Professor Pickering of Harvard College Observatory has taken photographs with an 8-inch double combination lens of about 44 inches' focal length, with exposures reaching two hours, of a portion of the sky round the great nebula in *Orion*, and finds that not only all the known nebulæ are photographed but that there is undoubted evidence of other nebulæ, twelve objects thus photographed not being in the New General Catalogue (*Mem.* R. A. S., vol. xlix. pt. I.). This has an additional interest from the fact that a close examination of a plate by the MM. Henry with three hours' exposure did not give signs of any new nebulæ. The region of sky photographed by Professor Pickering, it is true, is very rich, whilst that photographed by the MM. Henry is very poor.

Herr von Gothard, working with a 10-inch silver on glass reflector, has taken some remarkably fine photographs of the less-known nebulæ. Dr. H. C. Vogel of Potsdam gives in No. 2,854 of the *Astronomische Nachrichten* an account of some of these, with illustrations. That Herr von Gothard should have been able to obtain such exquisite photographs with such an aperture is very satisfactory, and should encourage the numerous owners of telescopes of about this size to follow his example.

The 5-foot reflector that has been under construction by Mr. Common during the last two years is completed. The effect of aperture in reducing the sizes of star discs on the photograph for a given amount of detail in the brighter portions of the nebula is shown in some recent photographs of the nebula of *Orion*, where, whilst the amount of faint detail of the surrounding portions is much greater than that given in the photographs taken in 1883, the distinct shape of the stars of the trapezium is retained.

The most successful efforts have been made by Mr. Roberts of Maghull, whose photographs of the great nebula in *Andromeda* and the nebulæ in the *Pleiades* have lately been exhibited to the Society. The latter photograph exceeds in the amount of detail it gives that taken by MM. Henry, and illustrated in the last report of the Paris Observatory, whilst the former photograph has certainly surpassed anything yet done in this line of research.

A. A. C.

The German Transit of Venus Observations.

The German Transit of Venus Commission, presided over by Dr. A. Auwers, has published vol. iii. of the Report, containing the observations made in 1882 by the four special expeditions to Hartford, Connecticut; Aiken, South Carolina; Bahia Blanca, La Plata; and Punta Arenas, in the Straits of Magellan; also those made on the Island of South Georgia (east of Cape Horn) by the members of the German Polar Expedition. The greater part of the volume is devoted to the heliometer work, which formed a special feature of the German plan of observation; but the whole of the observations made, of every class, are printed in the utmost detail, together with all that is necessary of the reductions. Vol. iv. of the Report of the Commission was published some years ago; it contains details of work done at home with the various instruments. Vols. i. and ii. have not yet appeared.

Dr. Wislicenus' Method of Determining Absolute Personal Equations in Transit Observations.

Dr. W. Wislicenus, of Strassburg, has recently published an interesting contribution to the literature of practical astronomy in a memoir entitled *Untersuchungen über den absoluten persönlichen Fehler bei Durchgangsbeobachtungen*, which contains a description of an apparatus invented by him for the determination of absolute personal equations, together with results obtained from a series of observations made with the apparatus attached to one of the transit instruments of the Strassburg Observatory. Dr. Wislicenus, fully recognising the necessity of determining personal equation with the instrument which is used in actual observation, imposed on himself three conditions as being of paramount importance:—(1) That the arrangement should be applicable to large transits or meridian circles; (2) that it should not impede the free motion of the instrument, so that determinations of personal equation may be made in the various positions in which the instrument is used for observing the heavens; (3) that the artificial star, the transits of which are to be observed, should traverse the entire field of the telescope, and in its motion should as much as possible resemble the actual motion of a real star. The artificial star in Dr. Wislicenus' apparatus is formed from the point of light which is seen in telescopes with central illumination of the field, and which proceeds from the small concave mirror which is placed on the inner surface of the objective. When viewed through a double concave lens of suitable focal length, placed in front of the eyepiece, this point of light closely resembles a moderately

bright star. The apparent motion of this artificial star across the transit threads is caused by the actual motion of the eyepiece in front of the plate carrying the threads, and is produced by an ingenious arrangement of clockwork. The automatic registration of the transits of the artificial star is effected by the passage of a platinum point, fixed to the eyepiece by a spring, across a brass plate on which are cut a series of fine lines perpendicular to the direction of motion of the eyepiece, and corresponding in number and relative distance to the transit threads. These lines are filled up with an insulating substance, so that, as the point in its motion across the plate passes one of the lines the electric current is broken and a register made. And the apparatus is to be adjusted so that the passage of the platinum point over one of the fine lines may correspond with the time when the artificial star appears to cross the corresponding transit thread.

The results obtained by Dr. Wislicenus with this apparatus are not altogether satisfactory, as, for the different rates of motion of the artificial star, he finds that his personal equation is almost a direct function of the zenith distance (being especially marked for the nadir position), thus suggesting the possibility that the observed variation with pointing of the telescope in zenith distance may really represent the varying effects of gravity on the apparatus. This is a point which ought to be further investigated in order that astronomers may determine what degree of confidence may be reposed in results obtained from the very ingenious and interesting arrangement described by Dr. Wislicenus.

A. M. W. D.

Improvements in the Methods of controlling the Driving-Clocks of Equatorials.

It is well known that Sir Howard Grubb has been for many years gradually perfecting Dr. Gill's and his own methods of controlling the driving-clocks of large equatorials, with the special object of enabling long exposures to be given to celestial photographs without the extremely tedious eye-pointing. Sir Howard Grubb has explained his methods to the Society; but in the minutes of the proceedings of the meeting of the Institution of Mechanical Engineers in Dublin, for 1888, July 31, he describes his latest improvements in considerable detail.

Papers read before the Society from March 1888 to February 1889.

1888.

Mar. 9. Ephemeris of the satellites of *Uranus*, 1888. A. Marth.

On invisible stars of perceptible actinic power. R. de Kövesligethy.

Telegraphic determination of the longitude of Haiphong. W. Doberck.

The total lunar eclipse of January 28, 1888, observed at the Dunsink Observatory. A. A. Rambaut.

Occultations of stars observed at the Liverpool Observatory, Bidston, Birkenhead, during the total eclipse of the Moon, 1888, January 28. J. Hartnup.

Total eclipse of the Moon, 1888, January 28. Rev. S. J. Perry.

Total eclipse of the Moon, 1888, January 28. W. F. Denning.

The lunar eclipse of 1888, January 28–29. Admiral Sir E. Ommanney.

Observations of double stars. W. Doberck.

Occultations observed at Harrow during the total eclipse of the Moon, 1888, January 28. Lieut.-Col. G. L. Tupman.

The total eclipse of the Moon, 1888, January 28. T. W. Backhouse.

On the orbit of 70 (*p*) *Ophiuchi*. J. E. Gore.

Observations of the variable star S (10) *Sagittæ*. J. E. Gore.

Orbit of the double star λ *Ophiuchi*. Professor S. Glasenapp.

Southern double stars. Rev. S. J. Johnson.

Occultations of stars during the total eclipse of the Moon, 1888, January 28, observed at the Armagh Observatory. J. L. E. Dreyer.

Ephemeris for physical observations of the Moon for the nine lunations from April 12 to the end of December 1888. A. Marth.

Photographs of the total lunar eclipse of 1888, January 28. Wm. Peck.

Observations of stars made at Glasgow Observatory in connection with the total eclipse of the Moon of 1888, January 28. Professor R. Grant.

Observations of stars occulted by the Moon during the eclipse of 1888, January 28, made at the University Observatory, Oxford. Professor C. Pritchard.

Observations of occultations of stars made at the Radcliffe Observatory, Oxford, during the total lunar eclipse of 1888, January 28. E. J. Stone.

April 13. An improved centering tube for reflecting telescopes. E. Crossley.

The Numerical Lunar Theory (extract from a letter to Mr. Knobel). Sir G. B. Airy.

Comet *Sawerthal* 1888 (extract from a letter to Mr. Knobel). David Gill.

On the occultations of Döllen's list of stars, observed at the Royal Observatory, Cape of Good Hope, during the total eclipse of the Moon, 1888, January 28. David Gill.

The total solar eclipse of 1889, January 1, in California; probable meteorological conditions at that time. Professor E. S. Holden.

The new southern comet. Observations made at Grahamstown, Cape of Good Hope. L. A. Eddie.

On the difference of longitude between Mr. Tebbutt's Observatory, Windsor, New South Wales, and the Government Observatories at Sydney and Melbourne. J. Tebbutt.

Sun-spots: their maximum and minimum periods, and their zones of greatest frequency. W. A. Ashe.

Note on *Mars*. R. A. Proctor.

Note on meteoric cosmogony. R. A. Proctor.

Observations of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *a* 1888. J. Tebbutt.

Sextant observations of Comet *a* 1888. Capt. J. Clarke.

May 11. Observation of the occultation of *Venus* by the Moon, 1888, March 9. J. Tebbutt.

Occultations of stars observed during the lunar eclipse of 1888, January 28. E. Nevill.

Observations of *Sappho* made at the Cambridge Observatory with the Northumberland equatorial and square-bar micrometer. A. Graham.

Observations of Comet *a* (Sawerthal) 1888, made at Launceston, Tasmania. A. B. Biggs.

Sextant observations of Comet *a* 1888, extracted from the meteorological log kept on board the barque "Atlantic." Captain R. Belding.

On the condition that in a double-image micrometer the value of a revolution of the micrometer screw be independent of the accommodation of the eye. Professor J. A. C. Oudemans.

Observations of the spectrum of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *a* 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Observations of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

A discussion of Greenwich observations of north polar distance with reference to the position of the ecliptic, and an annual variation in the value of the co-latitude. W. G. Thackeray.

The positions for 1750·0 and proper motions of 154 stars south of $-29°$ declination, deduced from a revision of Powalky's reduction of the star places of Lacaille's Astronomiæ Fundamenta. A. M. W. Downing.

Remarks on Sir G. B. Airy's Numerical Lunar Theory. Professor J. C. Adams.

Note on a simple method of applying electrical control to the driving clock of an equatorial. A. C. Ranyard.

Note on the total solar eclipse of 1889, December 21–22. J. R. Hind.

June 8. New arrangement of electrical control for driving clocks of equatorials. Sir H. Grubb.

Observations of Comet *a* 1888, made at Windsor, New South Wales. J. Tebbutt.

Observations of *Sappho* (80). Professor C. H. F. Peters.

Note on the Glasgow Star Catalogue. Professor R. Grant.

Description of a new observatory for a 3-foot reflector. E. Crossley.

Physical observations of *Saturn* in 1888. T. G. Elger.

On a large prime number. Sir G. B. Airy.

Observations of Comet *a* 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Note on Comet Sawerthal. Dr. L. Becker.

Observations of Comet *a* 1888 (Sawerthal), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on the visible spectrum of the great nebula in *Orion*. Dr. R. Copeland.

Nov. 9. Observations and elements of Comet Sawerthal, made at the Adelaide Observatory. Communicated by C. Todd.

Observation of the occultation of *Saturn* by the Moon, 1888, June 13. J. Tebbutt.

The ring nebula in *Lyra*. Professor E. S. Holden.

Observations of nebulæ at the Lick Observatory. Professor E. S. Holden and J. M. Schaeberle.

Results of observations of *Sappho* (80), made at the National Astronomical Observatory, Tacubaya, Mexico. Communicated by the secretaries.

Ephemeris of the satellite of *Neptune*, 1888–89. A. Marth.

Ephemerides of the satellites of *Saturn*, 1888–89. A. Marth.

Sextant observations of Comet *a* 1888 (Sawerthal), made on board the ship "Alcester." Captain L. C. Dart.

Observations of *Sappho* (80), made with the south equatorial and dark field filar micrometer, at the Melbourne Observatory. Communicated by R. L. J. Ellery.

Results of micrometric comparisons of *Jupiter* and β' *Scorpii* in May 1888. J. Tebbutt.

Height of a Perseid fireball. W. F. Denning.

Note on the occultation of χ *Orionis*, October 24, 1888. Rev. A. Freeman.

On an instrument for measuring the positions and magnitudes of stars on photographs, and for engraving them on metal plates. Isaac Roberts.

Results of recent investigations of stellar parallax made at the University Observatory, Oxford. Professor C. Pritchard.

On a compensating pendulum. R. Inwards.

On the spectra of R *Cygni* and *Mira Ceti*, and some stars with probably similar spectra. Rev. T. E. Espin.

Ephemerides for satellites of *Saturn*, 1888–89 (concluded). A. Marth.

Ephemeris for physical observations of the Moon, 1889, January 1 to April 1. A. Marth.

Observations of Comet *a* 1888 (Sawerthal), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

A table of the positions of observatories, with constants useful in correcting extra-meridian observations for parallax. Lieut.-Gen. J. F. Tennant.

Observations of Comet *e* 1888 (Barnard), made at Stonyhurst College Observatory. Rev. W. J. Crofton.

Observations of occultations of stars by the Moon taken at Stonyhurst. Rev. S. J. Perry.

Observations of *Jupiter's* satellites made at the Stonyhurst Observatory. Rev. S. J. Perry.

Dec. 14. Observations of comets made at the Orwell Park Observatory in the years 1887–88. J. I. Plummer.

Observations of Comet *a* 1888 (Sawerthal) and *e* 1888 (Barnard), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Photographs of the nebulæ M 31, *h* 44, and *h* 51 *Andromedæ*, and M 27 *Vulpeculæ*. Isaac Roberts.

On the determination of errors of graduation without cumulative error, and the application of the method to the scales of the Cape heliometer. David Gill.

Height of a Leonid fireball. W. F. Denning.

Photographs of the red end of the solar spectrum, from the line D to the line A. F. McClean.

On the retrogradation of the plane of *Saturn's* ring and of those of his satellites whose orbits coincide with that plane. Professor J. A. C. Oudemans.

Ephemeris for physical observations of *Jupiter*, 1889. A. Marth.

Note on the spectrum of Comet *e* 1888 (Barnard, September 2). Dr. R. Copeland.

Note on the values of the constants for the new Dearborn Observatory. Lieut.-Gen. J. F. Tennant.

Observations of Comet Barnard (1888, September 2), made at the Radcliffe Observatory, Oxford. E. J. Stone.

Note on an apparatus for correcting the driving of the motor clock of large equatorials for long photographic exposures. A. A. Common.

1889.

Jan. 11. Étoiles filantes de la période du 7–11 Août 1886, observées en Italie. F. Denza.

Photographs of the nebulæ in the *Pleiades* and in *Andromeda*. Isaac Roberts.

On methods of printing stellar charts from photographic negatives. Isaac Roberts.

The surface of the Sun in 1888. Rev. S. J. Perry.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1888. No. XII. Communicated by the Astronomer Royal.

Observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites, made in the year 1888, at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *e* 1888, with the transit circle, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Ephemeris of the satellites of *Uranus*, 1889. A. Marth.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1888, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on observations of nebulæ spectra at Hurstside Observatory. A. Taylor.

Ephemeris for physical observations of the Moon, 1889, April 1 to June 30. A. Marth.

List of Public Institutions and of Persons who have contributed to the Library &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The Norwegian Government.
The Government of the Netherlands.
British Association for the Advancement of Science.
British Horological Institute.
Camera Club.
City of London College.
Geological Society of London.
Institute of Civil Engineers.
Meteorological Office.
Photographic Society of Great Britain.
Physical Society of London.
Royal Geographical Society.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Zoological Society of London.
Belfast Natural History and Philosophical Society.
Bristol Museum and Library.
Cambridge Philosophical Society.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Edinburgh, Royal Society.
Kew Observatory.
Liverpool Astronomical Society.
Liverpool Free Public Library.
Manchester Literary and Philosophical Society.
Middlesex Natural History and Science Society.
Oxford, Radcliffe Library.
Stonyhurst College Observatory.

Amsterdam, Royal Academy of Sciences.
Batavia Observatory.
Berlin, German Transit of *Venus* Commission.
Berlin, Physical Society.
Berlin, Royal Academy of Sciences.
Berlin, Royal Observatory.
Berlin, Royal Prussian Geodetic Institute.
Berne University.
Bombay Branch of the Royal Asiatic Society.
Bordeaux Observatory.
Boston, American Academy of Arts and Sciences.
Brisbane, Queensland Branch of the Royal Geographical Society of Australasia.
Brussels, Royal Academy of Sciences.
Brussels, Royal Observatory.
Buda-Pesth, Hungarian Academy of Sciences.
Buenos-Ayres, Argentine Meteorological Office.
Canada, Geological and Natural History Survey.
Cape Town, South African Philosophical Society.
Cherbourg, National Academy of Sciences.
Christiania, Norwegian Meteorological Institute.
Christiania Observatory.
Cincinnati Observatory.
Coimbra Observatory.
Connecticut Academy of Arts and Sciences.
Copenhagen, Royal Academy of Sciences.
Delft, Polytechnic School.
Dorpat, Imperial Observatory.
Geneva, Society of Physics and Natural History.
Göttingen, Royal Society of Sciences.
Haarlem, Teyler Museum.
Halle, Leopold-Caroline Academy of Naturalists.
Harvard College Astronomical Observatory.
Helsingfors, Society of Sciences of Finland.
International Geodetic Association.
Italian Meteorological Society.
Italian Society of Sciences.
Japan, Seismological Society.
Kalocsa Observatory.
Kiel, University Observatory.
Leghorn, Technical and Nautical Institute.
Leipzig, Astronomical Society.
Leipzig, Royal Saxon Society of Sciences.
Lick Observatory of the University of California.
Lisbon, Royal Academy of Sciences.
Madras, Government Observatory.
Madrid Observatory.
Madrid, Royal Academy of Sciences.
Melbourne Observatory.
Melbourne, Royal Society of Victoria.

Mexico, Antonio Alzate Scientific Society.
Milan, Royal Observatory.
Moncalieri Observatory.
Montsouris Observatory.
Moscow, Imperial Society of Naturalists.
Moscow Observatory.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Naples, Academy of Sciences.
Natal Observatory.
New York, Cooper Union for the Advancement of Science.
Ottawa, Canadian Meteorological Office.
Padua Observatory.
Palermo Royal Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris, Philomathic Society of France.
Paris, Polytechnic School.
Paris Observatory.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Prague, Imperial Observatory.
Pulkowa Observatory.
Rio de Janeiro Observatory.
Rome, Italian Spectroscopic Society.
Rome, Royal Academy *dei Lincei*.
St. Petersburg, Imperial Academy of Sciences.
San Fernando Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya Observatory, Mexico.
Tasmania, Royal Society.
Tiflis, Physical Observatory.
Tokio, Imperial University of Japan.
Toronto, Canadian Institute.
Toulouse, Academy of Sciences.
Toulouse University, Faculty of Sciences.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Vienna, Imperial Academy of Sciences.
Virginia, Leander McCormick Observatory.
Washington, Office of the American Ephemeris.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Chief Signal Office.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.

Zurich, Central Meteorological Institute.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomische Nachrichten."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of "Engineering."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Die Naturforscher."
Editor of "Die Naturwissenschaftliche Rundschau."
Editor of "Die Naturwissenschaftliche Wochenschrift."
Editors of the "Observatory."
Editor of the "Sidereal Messenger."
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Messrs. Trübner & Co.
Prof. G. D. E. Weyer.
Dr. R. Wolf.
Clement Wragge, Esq.
Prof. C. V. Zenger.

ADDRESS

Delivered by the President, Mr. W. H. M. Christie, on presenting the Gold Medal of the Society to M. M. Lœwy.

It is now my pleasing duty to lay before you the grounds on which the Council have awarded the Gold Medal to M. Maurice Lœwy for his invention of the Equatorial coudé, of a new method of determining the constant of aberration, and for his other astronomical researches.

On examining the series of memoirs in which M. Lœwy has set forth his new methods of astronomical research, we are at once impressed by the originality of conception which characterises all his ideas, and by the thoroughness with which he has worked out the details necessary for the practical application of his new methods of observation. Observational astronomy has for many years past proceeded on such well-defined lines, that we have not unnaturally come to look rather to improvements of detail than to the introduction of new instruments for the advancement of our knowledge. It is, therefore, a matter of great satisfaction to find that M. Lœwy has placed at our disposal various methods of observation based on entirely new principles, and calculated to give astronomers improved and quite independent means of attacking several of the most important problems in our science.

The first of these new instruments with which I will deal is the Equatorial coudé.

It was in the year 1871 that M. Lœwy proposed his new form of equatorial, to which the name of "Equatorial coudé" has been given, and M. Delaunay, then director of the Paris Observatory, was so struck with the value of the principle, that he arranged for the construction of an instrument on this plan. M. Delaunay's death, however, interrupted the work, and the first Equatorial coudé, having an object-glass of $0^{m}\cdot27$, or about $10\frac{5}{8}$ inches aperture, was not completed till the year 1882. The success of this instrument was so marked that its value could not fail to be recognised, and it was not long before the construction of several larger equatorials on the same principle was commenced. At the present time six Equatorial coudés have been completed, and four of these are already mounted and in

regular use at the observatories of Paris, Lyons, Besançon and Algiers. The other two are intended for the observatories of Paris and Vienna.

In principle the Equatorial coudé may be described as an adaptation of the form of transit instrument with axial view to the requirements of an equatorial, by the addition of a plane mirror, inclined at 45°, outside the object-glass, this mirror being capable of rotation about the axis of the telescope, so as to reflect into the latter the rays from any object in a perpendicular plane. The axis of the instrument is mounted as a polar axis between two piers, the telescope being broken at a right angle near the lower pivot, so that the rays from the object-glass are reflected by an internal mirror up the polar axis to the hollow upper pivot, where the image is formed. The rotation of the outer mirror thus brings into the field the image of any object in the hour-circle perpendicular to the object-end of the telescope, and by the rotation of the polar axis, as in an ordinary equatorial, the telescope is directed to any hour-angle. The declination-axis in the Equatorial coudé is the axis of the object end of the telescope about which the outer mirror turns, and the declination-circle placed at the eye-end, in the same plane with the hour-circle, is connected with the axis of the outer mirror by gearing, so that the observer at the stationary eyepiece has both the hour and declination circles immediately under his eye. He can thus direct the instrument to any object without moving from his chair, and his observations are made under the most favourable conditions for his own comfort, similar to those under which the microscope is used by the student of natural history. The observing room, which may be artificially warmed, is quite separated from the object-glass, and other external parts of the instrument. These latter are protected from the weather by a suitable hut, which can be rolled away on rails before observing, so that the optical parts of the equatorial are in the open air under the best conditions for establishing an equilibrium of temperature.

The importance of obtaining the favourable conditions for observation secured by M Lœwy's Equatorial coudé has long been recognised, and various attempts have been made to enable the observer to command any part of the sky without changing his position. In 1858 Dr. Steinheil proposed* a new method of mounting a reflector, so that the axis of the concave mirror formed the polar axis, the rays from a star being reflected down the axis to the concave mirror by a plane mirror, which could be rotated about a declination axis and a polar axis. The observer looked down the polar axis through a hole in the plane mirror, but with this arrangement he could not observe stars much north of the equator unless the plane mirror were made very large, and the range of the equatorial was thus very restricted. A more ex-

* *Astron. Nachrichten*, No. 1138, *Monthly Notices*, vol. xix. p 56.

tended range might be obtained by interchanging the concave and plane mirrors, so that the observer would look up in the direction of the pole; but the concave mirror and its support would block out the view of the region near the pole, and of all the sky below the pole. Sir H. Grubb has applied the same principle to the construction of a siderostatic refractor.

As compared with Dr. Steinheil's form the Equatorial coudé possesses the great advantage of commanding every part of the sky, the arm of the telescope below the elbow being made long enough to project beyond the sides of the observing room when viewing objects near the meridian.

The siderostat of Foucault, though useful for many purposes, is open to the same objection as Dr. Steinheil's, of not permitting of a view of every part of the sky; and there is the further difficulty that the apparent direction of the diurnal motion is continually changing. In the Equatorial coudé this direction changes with the declination, but M. Lœwy has now arranged that the micrometer is turned with the declination circle, and is thus always set to the zero of position angle.

The success obtained by M. Lœwy in the construction of the Equatorial coudé is due to the following circumstances:—

1. The absence of flexure in the mirrors, which are made much thicker than usual.
2. The more perfect achromatism secured by the greater focal length which this form of mounting allows of.

The first condition was established by careful experiment, which showed that in order to avoid deformation by flexure the thickness of a mirror should be between $\frac{1}{5}$ and $\frac{1}{6}$ of the diameter instead of $\frac{1}{9}$ or $\frac{1}{10}$ as had been usual hitherto.

As regards achromatism M. Lœwy urges that, in order to be able to see better with a larger object-glass, the achromatism must be made more perfect, and that, therefore, the ratio of focal length to aperture must increase with the aperture in order to diminish the effect of the secondary spectrum.

Notwithstanding the two reflections, the definition obtained with the Equatorial coudé appears to be very good, the components of ω *Leonis*, distant only $0''\cdot5$, having been separated with the Paris instrument which has an object-glass of $0^{\mathrm{m}}\cdot27$, or about $10\frac{5}{8}$ inches. With one of the new instruments of $0^{\mathrm{m}}\cdot31$, or $12\frac{1}{4}$ inches aperture, M. Trépied at Algiers easily divided γ^2 *Andromedæ*. The loss of light by the two reflections from silvered mirrors is computed by M. Lœwy at only 12 per cent. and it would seem that it is at any rate very small, as successful observations of a minor planet of 13·5 magnitude were obtained with the Paris instrument as well as of very faint nebulæ and comets. The comet 1885 *d* (Fabry) was discovered with this instrument.

One of the objects which M. Lœwy had in view in planning

his Equatorial coudé was to obtain greater stability than is attainable with ordinary equatorials, and to make the measurement of large angular distances possible. The form of mounting of the Equatorial coudé seems peculiarly adapted to give great stability, provided the fixity of the mirrors in their cells can be secured, and this is a condition to which M. Lœwy has given special attention. Each mirror rests in its cell on thick felt or flannel, and is held by three clips, which are just brought into contact with it when in the horizontal position, as tested by the disappearance of the least trace of light between the clip and its reflected image. This adjustment being made for the horizontal position, in which the weight of the mirror has its full effect, perfect contact between the mirror and its clips will be maintained in all positions.

M. Lœwy, in conjunction with M. P. Puiseux, has investigated very completely the theory of the instrumental adjustments of the Equatorial coudé, including the effect of flexure of the polar axis and of the telescope arm, and has shown the relation of his formulæ to those for ordinary equatorials. He arrives at the two following conditions of optical adjustment as sufficient for astronomical purposes:—

1. The axis of the telescope arm should be perpendicular to the polar axis.
2. The interior mirror should reflect to the centre of the field a ray entering the telescope along the axis of the arm, supposed to be perpendicular to the polar axis.

The discussion of the instrumental errors of the Paris instrument, partly by astronomical observations, and partly by means of a collimator attached to the mounting of the exterior mirror, shows a very satisfactory accordance in the determinations on different days, and in the result the instrumental errors were found to be very small, the largest amounting only to 23″. The coefficients of flexure are, however, rather larger quantities, being 91″ and 53″ for the polar axis and telescope arm respectively, as found by means of the collimator. It may be expected that in the new instruments the effects of flexure would be very much less, as important improvements have been made in their mechanical construction.

It is not a little remarkable that the first instrument made on this new principle should have given such excellent results, both optically and mechanically, and its success is evidence of the thoroughness with which M. Lœwy has worked out his idea, and of the skill with which MM. Henry and M. Gauthier have respectively carried out the optical and mechanical portions of the instrument.

I now pass on to M. Lœwy's new method of determining the constant of aberration. It is hardly necessary to insist on the importance of this constant, not only for obtaining the true positions of the stars, but, in a higher degree, for the determina-

tion of the solar parallax by means of the velocity of light. It must be admitted that the nine independent determinations of the constant of aberration made at Pulkowa with three different instruments show a satisfactory accordance, but in the opinion of M. Nyrén, who has published the latest researches on the subject, none of these can be asserted to be free from systematic error. M. Nyrén's definitive value is 20''·492, exceeding by 0''·047 W. Struve's original value, which has hitherto been generally used by astronomers. Under these circumstances M. Lœwy's method, which is based on differential measures with an equatorial, constitutes a new departure of great value in astronomy of precision, and its value is enhanced by the circumstance that it is also applicable to the determination of the constant and law of refraction.

The principle of M. Lœwy's method is the measurement of the angular distance between two stars by means of a double mirror, formed by silvering two faces of a large prism of glass, and placed in front of the object-glass of an equatorial. The double mirror is capable of rotation about the axis of the telescope, so that by reflection from the two silvered surfaces the images of two stars in different parts of the sky may be brought into the field side by side, and the distance between them measured in the direction of the common plane of reflection. In his memoir on the determination of refraction by the new method, M. Lœwy proves that the projection of the distance between the two images on the trace of the common plane of reflection is independent of the rotation of the equatorial, of any movements of the double mirror, and of the displacement of the images by the diurnal motion, when the observation is not made rigorously in the plane of reflection.

M. Lœwy's exposition of his method of determining the constant of aberration is contained in a series of communications made to the French Académie des Sciences and published in the *Comptes Rendus*, vols. civ. and cv. In giving an account of this investigation, I will proceed at once to the general method for determining aberration, which M. Lœwy discusses after treating some special cases.

The determination of aberration requires the measurement of the distance between a pair of stars at successive epochs when the effect of aberration on the angular distance is reversed. The observations are made when the two stars have the same altitude, so that the effect of refraction is a minimum, and the comparison of the two measures gives a multiple of the constant of aberration, which is independent of all instrumental errors and also of precession and nutation, as the distance between two stars is unaffected by any movements of the earth's axis or of the ecliptic. There is the further advantage in the new method, that the effect of aberration as measured is much greater than in the ordinary methods of observation.

But the result might be affected by change of refraction or

by alteration in the angles of the double mirror resulting from thermal expansion between the two epochs of observation, and M. Lœwy has therefore imagined a general method of observation which eliminates any possible effects of the kind, as well as methods applicable to special cases which determine any changes due to refraction or expansion of the mirror.

The essence of the general method is that two pairs of stars are observed, the four stars being selected so that at the time of observation they are all simultaneously at the same altitude and that the effects of aberration on the two arcs connecting the stars of each pair are large and of opposite sign. Thus the two arcs formed respectively by the two pairs of stars are compared simultaneously both at the first and at the second epochs.

The first point for investigation is the effect of aberration on the angular distance between a given pair of stars. From the geometrical conditions M. Lœwy arrives readily at the result that the effect is proportional to the cosine of the angle between the median* of the arc and the direction of the Earth's motion.

Calling Δ the angular distance between two stars,
p the angle between the median of the arc joining them and the direction of the Earth's motion,
and k the coefficient of aberration,

the effect of aberration is given by the formula

$$d\Delta = 2k \sin \frac{\Delta}{2} \cos p.$$

It readily follows from this that the effect of aberration on the difference of the two arcs connecting two pairs of stars will be greatest when the two medians are on the same vertical circle on opposite sides of the zenith. Under these circumstances, the effect of aberration on the difference of the two arcs is equal to

$$4k \sin \frac{\Delta}{2} \sin \frac{\Delta'}{2} \cos \mathrm{L},$$

Δ' being the angular distance between the two medians, and L the angle between the direction of the Earth's motion and the line of intersection of the vertical plane through the medians with the horizon. Thus the effect is proportional to the cosine of this angle, and the greatest effect will be obtained when the vertical plane of the medians, the ecliptic and the horizon intersect in the same line, and the observations are made at the two epochs six months apart when the direction of the Earth's motion coincides with this line, L having the values 0° and 180° at the two epochs respectively. In that case the effect of aberration on the difference of the two arcs has opposite signs at the two

* The median is the line bisecting the angle between the directions of the two stars.

epochs, and the comparison of the two sets of measures of the two arcs gives

$$E = 8k \sin\frac{\Delta}{2}\sin\frac{\Delta'}{2},$$

where E is the difference of the two measures of difference of arcs at the first and second epochs respectively.

The next point for consideration is the choice of the angle for the double mirror, the angular distance (Δ) between the two stars in each pair being necessarily twice this angle. Obviously the altitude at which the observation of the four stars is made diminishes as Δ and Δ' increase, and M. Lœwy shows that the maximum effect at any given altitude is obtained by making $\Delta'=\Delta$, or the angular distance between the medians the same as that between the two stars in each pair. He then gives the following table of the altitude h and of the effect of aberration $\frac{E}{k}$ corresponding to the several values of the angle of the double mirror a :—

a	30°	35°	40°	45°	50°	55°	60°
h	48° 35′	42° 9′	35° 58′	30° 0′	24° 24′	19° 12′	14° 29′
$\frac{E}{k}$	2·0	2·6	3·3	4·0	4·7	5·4	6·0

M. Lœwy concludes that the angle of the double mirror should not exceed 50°, and he considers that on the whole it would be well to make it 45°, so that the altitude of the stars would be 30°, and the angular distance for each pair 90°. Under these conditions observations made at two epochs six months apart would give as the quantity measured four times the constant of aberration, while the ordinary methods of observation only give at the maximum a measure of twice the constant. But in order to avoid daylight observations M. Lœwy thinks it would be advisable to be satisfied with a slightly smaller coefficient of k (the constant of aberration), say three instead of four, which would reduce the interval between the two epochs to about ninety-eight days, and by combining the observations in the first five weeks with those in the last five, a series of equations would be obtained in which the coefficient of k would vary from three to one, the mean value being about two. All the observations could then be made in the night hours.

Besides the general method of observation just described, M. Lœwy has, as already mentioned, devised two methods applicable to special cases which are well suited to give independent determinations of the constant of aberration.

The first method consists in the observation of two pairs of stars, of which one pair gives at the end of two or three months the measure of twice the constant of aberration, and the other, completely unaffected by aberration, exhibits the effect of tem-

perature on the double mirror. The first pair of stars should be in the neighbourhood of the ecliptic; the second pair is, as will be seen from geometrical considerations, to be chosen so that the latitudes of the two stars are the same, and that their longitudes differ by 180°, in order that the arc joining them may be unaffected by aberration.

This method is, however, not applicable at observatories within 20° of the equator, and on this account, as well as to give another independent determination of the constant of aberration, M. Lœwy proposes a second method according to which the angular distance of a single pair of stars near the ecliptic is to be observed for a period of three months or longer, the measures in the first and last twenty-five days of the period being used to determine the aberration, and those in the intermediate forty days to deduce the effect of temperature on the double mirror.

The question of the adjustment of the double mirror remains to be mentioned. This must be mounted so as to turn about the optical axis, and this axis should coincide nearly with the axis of figure. The effects of any movements of the double mirror will then be as follow:—

1. In turning round the axis of figure the two images are displaced in opposite directions, but perpendicularly to the trace of the common plane of reflection.
2. In turning round an axis in this plane and perpendicular to the axis of figure the two images move in the same direction perpendicularly to the trace of the plane of reflection.
3. If the double mirror turns about an axis perpendicular to the plane of reflection, the two images move along the trace without changing their relative distance.

Reference has already been made to the applicability of M. Lœwy's new method to the determination of refraction at various altitudes. This was, in fact, the immediate object which M. Lœwy had in view when he devised the method, and his investigation of the conditions of the problem was communicated to the French Académie des Sciences early in 1886, the year before he published his memoir on aberration.

In his series of papers on the determination of refraction published in the *Comptes Rendus*, vol. cii., M. Lœwy first gives a method for determining the constant of refraction, the law according to which refraction varies with the altitude being known. A pair of stars is observed when refraction has its maximum effect on their angular distance, and again when the effect of refraction is a minimum. For the maximum effect one of the stars must be on the horizon. and the other in the same vertical circle with it, while for the minimum both stars must be at the same altitude. M. Lœwy then finds that the greatest variation of refraction will be obtained with an angle of 30° for the double mirror, but as with this there would be (for

the latitude of Paris) a minimum interval of 6^h 35^m between the two epochs of observation, he prefers to take an angle of 45° for the double mirror, sacrificing only 15″ in the effect of refraction, while reducing the interval between the observations to 4^h 44^m. This is the minimum value of the interval found by selecting the pair of stars so that their common zenith distance at the second epoch is equal to the angle of the double mirror, or half the angular distance between the two stars.

The geometrical conditions thus found by M. Lœwy to give the maximum effect in the minimum interval of time between the observations may be somewhat modified in practice, provided the angular distance between the stars does not differ by more than a few minutes from twice the angle of the double mirror. M. Lœwy has thus been able to find some twenty pairs of bright stars suitable for the determination of refraction by this method. In its practical form the method consists in the measurement of the angular distance between a pair of stars 90° apart when one of the stars is near the horizon and the other near the zenith, and again when both the stars are at about the same altitude. It is not necessary that at the former epoch the low star should be very near the horizon, for, as M. Lœwy points out, observations may be advantageously continued till the altitude is nearly 20°, and thus the constant of refraction may be determined from observations which are practically unaffected by any uncertainty in the law of refraction.

It will readily be understood that the observation of the low star may be made either when it is rising or when it is setting. In the latter case the observation of the stars at equal altitude would precede that for which one of the stars is setting. By combining the observations of two pairs of stars chosen so that the first pair is rising when the effect of refraction on the second is a minimum, and that the first pair is at the minimum when the second pair is setting, the influence of any change in the angle of the double mirror will be eliminated by taking the mean of the two determinations, while the difference of these will give four times the change of angle in the interval, thus affording a precise determination of any such change, if it exists.

Various other methods are proposed by M. Lœwy for determining the refraction at any altitude without assuming its law of variation. These methods, however, appear to involve practical difficulties, as they either assume the absence of irregular variations in the refraction at an altitude of 10°, or require the construction of several double mirrors with different angles. They may be considered as supplementing the first method; and they are of interest as giving a direct measure of refraction independently of any theory.

The practical determination of the constants of aberration and refraction by the new method is being carried out by M. Lœwy and M. P. Puiseux with the Equatorial coudé of the Paris

Observatory, and the series of observations made during the past twelve months confirms in the most satisfactory manner the theoretical conclusions. M. Lœwy finds that the variations of the distances are really free from systematic errors, and he considers that the constant of refraction will be more accurately determined from a few nights' observations with his new method than from years of meridian observations.

In conclusion I can only allude in the briefest terms to the other important researches for which astronomers are indebted to M. Lœwy. The following is a summary of the other new methods of instrumental research which M. Lœwy has devised in the last few years:—

1. A method for determining the flexure of transit-circles at various zenith distances by means of an optical apparatus inserted in the central cube. This has been used to find the flexure of two transit-circles at the Paris Observatory, the absolute values of the flexure for the two ends of the telescope and for the axis being independently determined.

2. A method for obtaining the latitude without making use of the declinations of fundamental stars.

3. A general method for determining right ascensions without relying on assumed right ascensions of polar stars.

4. A method for finding on each night the absolute declinations of stars without the necessity for observations of polar stars at upper and lower transit.

5. Methods for determining directly the two co-ordinates of polar stars without a previous investigation of the instrumental errors.

All these methods except the first are based on the observation of close circumpolar stars in R.A. and N.P.D. out of the meridian at various points of the circles described by them. Conjugate observations either of a single star or of a pair of stars having the same N.P.D. are made with a transit-circle, having a field of view of 2°, at equal intervals (about two hours) before and after meridian passage or before and after passage over the hour-circle of 6^h east or west. The special methods of observation are developed in a series of communications to the French Académie des Sciences made in the years 1883 and 1885, and during the last two years M. Renan has applied these new methods to a determination of the latitude of the Paris Observatory based on 80 very accurate results.

The account which I have given of M. Lœwy's inventions and researches is necessarily very imperfect, and I have had to pass over many points of interest in the application of his methods. But I trust that the summary I have made will at any rate suffice to show the very high importance of M. Lœwy's labours, and that they fully deserve the recognition which is to-

day given to them, whether we have regard to the originality of the methods or to the value of the results which are to be obtained from them.

The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms:—

Dr. Huggins,—In transmitting this medal to M. Lœwy I would ask you to assure him of our very high appreciation of the services which he has rendered to Astronomy by the invention of his Equatorial coudé and of his new methods for determining important astronomical elements, and to express our hope that his life and strength may long be spared to enable him to continue the successful application of the instrumental means he has devised for the advancement of our science. We deeply regret that we are deprived of his presence to-day, through the effects of a serious accident, but trust that he will ere long be completely restored in health and vigour.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

W. H. M. CHRISTIE, Esq., M.A., F.R.S., Astronomer Royal.

Vice-Presidents.

J. C. ADAMS, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
J. W. L. GLAISHER, Esq., M.A., Sc.D., F.R.S.
E. J. STONE, Esq., M.A., F.R.S., Radcliffe Observer.
Lieut.-Gen. J. F. TENNANT, R.E., C.I.E., F.R.S.

Treasurer.

A. A. COMMON, Esq., F.R.S.

Secretaries.

A. M. W. DOWNING, Esq., M.A.
E. B. KNOBEL, Esq.

Foreign Secretary.

WILLIAM HUGGINS, Esq., LL.D., D.C.L., F.R.S.

Council.

Capt. W. DE W. ABNEY, C.B., R.E., F.R.S.
ARTHUR CAYLEY, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
Hon. Sir JAMES COCKLE, M.A., F.R.S.
WARREN DE LA RUE, Esq., M.A., Ph.D., D.C.L., F.R.S.
EDWIN DUNKIN, Esq., F.R.S.
GEORGE KNOTT, Esq., B.A., LL.B.
Capt. WILLIAM NOBLE.
Rev. S. J. PERRY, D.Sc., F.R.S.
W. E. PLUMMER, Esq.
E. J. SPITTA, Esq.
Lieut.-Col. G. L. TUPMAN, R.M.A.
H. H. TURNER, Esq., M.A., B.Sc.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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W. H. M. Christie, M.A., F.R.S., President, in the Chair.

The Rev. Charles Douglas Percy Davies, M.A., Ringmer, near Lewes,

was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended :—

Edward Carpmael, B.A., late Scholar of St. John's College, Cambridge, Fellow of the Institute of Patent Agents, Assoc. Inst. C.E., The Ivies, St. Julian's Farm Road, West Norwood, S.E. (proposed by Warren de la Rue); and

James George Petrie, 15 Mercers Road, Holloway, N., Journalist (proposed by A. Cowper Ranyard).

Preuves de la nutation diurne; mode d'observation propre à la mettre en évidence en une seule soirée. Par F. Folie, Directeur de l'Observatoire royal de Bruxelles.

(*Communicated by the President.*)

Pendant l'année 1888, j'ai recherché les méthodes qui sont les plus propres à manifester le mouvement diurne de l'axe de la croûte terrestre, et à en déterminer les constantes, et j'ai appliqué ces diverses méthodes à des observations faites en différents lieux.

Ces procédés peuvent se diviser en deux classes, selon qu'ils sont fondés sur des observations faites en deux lieux, distants, autant que faire se peut, de 6^h en longitude, ou sur des observations faites en un même lieu.

Parmi les premiers, je signalerai particulièrement à l'attention des astronomes le procédé qui consiste à déterminer les constantes de la nutation diurne par la comparaison des catalogues de deux observatoires différents ; j'ai fait choix, dans ce but, des nouveaux catalogues de Paris, de Poulkova et de Bruxelles, que j'ai comparés à ceux de Washington.

Si un astronome voulait effectuer la détermination des constantes de la nutation diurne au moyen de la comparaison d'autres catalogues de deux observatoires situés à peu près à 6^h de distance en longitude, voici les formules dont il devrait faire usage.

$\Delta^2\alpha$ et $\Delta^2\delta$ désignent les différences en A.R. et D. d'une même étoile déterminée dans les deux observatoires (occid., orien.), l leur différence de longitude, c la somme $\cot\omega + 0{\cdot}4354$, ω l'obliquité de l'écliptique, ϵ l'erreur accidentelle de chacune des différences individuelles :

$$(1)\quad \Delta^2\alpha + (c\sin 2\alpha + \tan\delta\cos\alpha)x + [-c\cos 2\alpha + \tan\delta\sin\alpha]\,y = \epsilon\,;$$

$$(2)\quad \Delta^2\delta + \sin\alpha x - \cos\alpha y = \epsilon.$$

On peut appliquer isolément le système des équations (1) ou celui des équations (2) à un grand nombre d'étoiles, et chercher x et y par la méthode des moindres carrés. On peut aussi appliquer simultanément les systèmes (1) et (2).

Connaissant x et y on aura $\tan 2L_m = \frac{x}{y}$, L_m désignant la longitude orientale du premier méridien par rapport au méridien mitoyen entre les deux observatoires et le coëfficient de la nutation diurne sera égal à

$$\frac{x}{2{\cdot}312\sin l\sin 2L_m} \text{ ou à } \frac{y}{2{\cdot}312\sin l\cos 2L_m}.$$

Je reviendrai ci-dessous sur un autre procédé, qui permet de démontrer, en une seule nuit, l'existence de la nutation diurne.

Mais auparavant, je crois utile de signaler aux astronomes les résultats des différentes déterminations qui ont éte faites jusqu'à ce jour.

Méthodes.	Observatoires.	N_d	Longitude E. de Paris.
			h m
Comparaison des catal. en A.R.	Paris–Washington	0,0885 ± 0,0084	5 31 ± 2^m,8
" " D.	"	0,508	4 26
" " A.R.	Poulkova–Washington	0,1655 ± 0,006	8 22 ± 9^m
" " D.	"	0,2353 ± 0,006	8 36 ± 1^m
" " A.R.	Bruxelles–Washington	0,071	12 27,5
" des A.R. de δ *Ursæ Min.*	Paris–Washington	0,056	8 52
Observation de la Polarissime	Kieff	0,209	9 19
" α *Ursæ Min.*	Harvard College	0,077	9 29
" 117 Pol. Zone	Bonn	0,136	11 1
" 297 "	"	0,22	12 7
" λ *Ursæ Min.*	Bruxelles	0.10	10 25
" α "	Poulkova	0,18	11 45
" δ "	"	0,32	8 41
" α "	Greenwich	0,12	10 17
" α "	Washington	0,17	11 36
" σ *Octantis*	Cordoba	0,11	10 17
" α *Lyræ*	Washington	0,095	8 48
2 Observations de *t* et Q (26 sept.)	Cointe (Liège)	0,19	9 43
4 " de P (2 déc.)	"	0,45	11 26
2 " de P et Q (4 déc.)	"	0,30	4 21
2 " " (7 déc.)	"	0,20	10 37

Ces résultats sont, certes, suffisamment probants pour décider tout astronome à admettre, comme absolument certaine, l'existence de la nutation diurne.

On a vu, en partie, dans les derniers exemples donnés, combien il est aisé d'en vérifier l'existence, j'allais dire d'en déterminer les constantes, par des observations, faites à 6^h environ d'intervalle, d'une ou de deux étoiles très voisines du pôle.

Aussi, je ne doute pas que les observatoires, qui possèdent une lunette méridienne assez puissante, ne s'empressent de poursuivre, en même temps que moi, ces observations.

Carte des Circompolaires à 15′ du Pôle.

La petite carte ci-jointe, dans laquelle les lettres minuscules sont celles employées par Carrington, permettra de trouver immédiatement les trois étoiles les plus propres à la détermination dont il s'agit, t, P et Q.

Je ferai remarquer que j'ai cherché, pendant les mois d'octobre et de novembre, à effectuer cette détermination par l'observation des deux étoiles t et t', situées à 12^h environ de distance en A.R., ce qui serait très avantageux en théorie ; mais que mes observations ont toutes conduit à des résultats beaucoup trop forts pour la constante de la nutation diurne. J'attribue ce mauvais résultat à ce que l'étoile t' éloignée de $8'{\cdot}5$ environ du pôle, était située, dans l'une des observations, vers l'extrémité du champ, et qu'il s'y produisait une altération dans la position de l'image de l'étoile, fait qui semble avoir été constaté déjà par M. Loewy.*

* A Bruxelles, même au cercle méridien de Repsold, de 6 pouces d'ouverture, on ne voit que très difficilement l'étoile t, absolument pas P et Q, probablement à cause de l'éclairage de l'atmosphère par le gaz de le ville.

A moins donc de faire des recherches très précises sur la distance *réelle* du fil mobile au centre du réticule, lorsqu'il en est éloigné de plus de 3′, il faut s'astreindre à ne pas observer des étoiles plus éloignées du pôle.

Parmi les trois étoiles que j'ai trouvées dans le voisinage du pôle, l'une seulement, *t*, est de 10½ grandeur environ, les deux autres P et Q sont de 12ᵉ à 13ᵉ seulement.

A la rigueur, on pourrait se borner à observer la première; on a vu, par l'exemple du 2 décembre, que, des observations d'une seule étoile, on peut déduire les constantes de la nutation diurne. Mais il est plus expéditif, et plus sûr, d'en observer plusieurs à la fois.

Ce procédé offre le grand avantage d'éliminer, pour ainsi dire entièrement, toutes les erreurs de la collimation, d'azimuth, d'inclinaison, et de déviation de la verticale.

Je me suis borné à l'observation des étoiles P et Q en azimuth, n'ayant pu modérer suffisamment l'éclairage des fils horizontaux du réticule pour pouvoir pointer ces étoiles très faibles, en déclinaison.

Ce sont les formules relatives à ce cas que je communiquerai ici. Celles qu'on pourrait employer, dans le cas où l'on aurait fait des observations de la déclinaison de l'étoile, sont d'un usage plus simple, et les astronomes les connaissent.

Voici, d'abord, les formules dont je fais usage pour déduire les A.R. de l'étoile de deux observations azimutales.

De l'équation connue—

$$\tan\delta\cos\phi = \sin\phi\cos(t-\alpha) - \sin(t-\alpha)\cot A \quad . \quad . \quad . \quad (1)$$

dans laquelle ϕ désigne la latitude, t l'heure sidérale du lieu et de l'instant de l'observation, α, δ, A l'A.R., la D. et l'azimut de l'étoile, on tire d'abord, en l'appliquant à deux observations consécutives, et en commençant par négliger le terme en $\sin\phi$, qui est très petit en général, vis à vis des deux autres, pour des étoiles distantes de 3′ environ du pôle:—

$$\frac{\sin(t_1-\alpha_1)}{\sin(t_2-\alpha_2)} = \frac{\tan A_1}{\tan A_2};$$

et de là,

$$\tan\left(\frac{t_1+t_2}{2}-\alpha\right) = \tan\frac{t_2-t_1}{2}\;\frac{\sin(A_2+A_1)}{\sin(A_2-A_1)} \quad . \quad . \quad (2)$$

Cette équation donne la moyenne α des A.R. de l'étoile aux deux instants de l'observation.

On peut maintenant appliquer l'équation (1) au calcul des valeurs de la déclinaison de l'étoile à ces deux instants.

Si l'on pose

$$\tan q = \tan(t-\alpha)\cot A\sec\phi \quad . \quad . \quad . \quad . \quad . \quad (3)$$

on aura, en effet,

$$\tan\delta = \frac{\cos(t-\alpha)\sin(\phi-q)}{\cos\phi\cos q} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

De cette équation (4) on tirera les valeurs de δ pour les deux observations.

Enfin, faisant

$$\frac{\cot A}{\sin \phi} = \cot A^1,$$

on tirera de l'équation (1)

$$\sin (A^1 - t + \alpha) = \sin A^1 \tan \delta \cot \phi; \quad . \quad . \quad . \quad . \quad (5)$$

Cette dernière équation, appliquée également aux deux observations, donnera les deux valeurs correspondantes de l'A.R. de l'étoile.

La différence de ces deux valeurs fournira une relation entre les deux constantes de la nutation diurne, savoir, son coëfficient N_d, et la longitude orientale L du premier méridien par rapport au lieu de l'observation.

Si l'on combine de la même manière la seconde observation avec la troisième, on aura une seconde équation analogue, et les deux inconnues seront déterminées.

Si l'on désigne par $\Delta\alpha$ la différence des A.R. observées (à 6^h environ d'intervalle), par l cet intervalle de temps, par m et n respectivement les expressions $\cot \epsilon + \sin \alpha \tan \delta$ et $\cos \alpha \tan \delta$, par Σ_1 et Σ_2 des fonctions des arguments de la nutation, dont l'expression sera donnée ci-dessous, les équations à former, qui se déduisent de ma théorie de la nutation diurne, sont, si l'on néglige les termes qui ne renferment pas $\tan \delta$;

$$\Delta\alpha = 2 \sin l \tan \delta \left\{ \begin{array}{l} + [\Sigma_1 \sin (\alpha + l) - \Sigma_2 \cos (\alpha + l)] y \\ [\Sigma_1 \cos (\alpha + l) + \Sigma_2 \sin (\alpha + l)] x \end{array} \right\} \quad . \quad . \quad . \quad (7)$$

Dans cette équation—

$$x = \mathrm{N} \quad \sin 2\mathrm{L}\,; \quad y = \mathrm{N}_d \cos 2\mathrm{L}\,;$$

quant aux fonctions Σ_1 et Σ_2, en voici les expressions numériques, dans lesquelles les différents arguments désignent des longitudes moyennes; on y a donné les coëfficients numériques par leurs logarithmes, et laissé de côté ceux, assez nombreux, qui sont inférieurs à 0·01.

$$\begin{array}{rl} \Sigma_1 = & -[0{\cdot}062716] - [9{\cdot}12682] \cos \text{☊} + [9{\cdot}89846] \cos 2\,\text{☾}, \\ & -[9{\cdot}11376] \cos (\text{☾} - \Gamma^1) + [9{\cdot}18342] \cos (3\,\text{☾} - \Gamma^1), \\ & +[9{\cdot}12574] \cos (2\,\text{☾} - \text{☊}) + [9{\cdot}55410] \cos 2\odot, \\ \Sigma_2 = & -[9{\cdot}25466] \sin \text{☊} + [9{\cdot}93551] \sin 2\,\text{☾}, \\ & +[9{\cdot}22027] \sin (3\,\text{☾} - \Gamma^1) + [9{\cdot}25207] \sin (2\,\text{☾} - \text{☊}), \\ & +[9{\cdot}59136] \sin 2\odot. \end{array} \quad . \quad . \quad . \quad (6)$$

Dans ces expressions les symboles ☊, ☉, ☾, etc., désignent les longitudes moyennes.

Appliquant la méthode qui vient d'être exprimée à la détermination des constantes de la nutation diurne au moyen des

observations des étoiles t et Q faites à Cointe (Liège) les 26–27 septembre 1888.

1888.		Heure sid.	Azim. Obs.	
		h m s	′ ″	
Sept. 26	t	20 19 26	3 29	W
26	Q	20 27 5	5 18	,,
27	t	1 14 0	4 30	,,
27	Q	1 27 45	1 19	E

L'application de la formule (2), qui précède, a donné d'abord,

$$\text{pour } t,\ a = 17^h\ 25^m\ 19^s{\cdot}9$$
$$\text{,, } Q,\ a = 12^h\ 36^m\ 51^s{\cdot}4$$

D'où l'on a déduit, au moyen des formules (3) et (4),

$$\text{P.D.} = \overset{t}{3'\ 13''{\cdot}0} \qquad \overset{Q}{3'\ 47''{\cdot}2}$$

et par les formules (5)

$$a = \begin{cases} 17^h\ 25^m\ 20^s{\cdot}77 & 12^h\ 36^m\ 37^s{\cdot}89 \\ 17\ 25\ 58{\cdot}50 & 12\ 36\ 47{\cdot}72 \end{cases}$$

correspondantes aux heures sidérales des observations.

D'où l'on tire

$$\Delta a = \overset{t}{-37^s{\cdot}73} \qquad \overset{Q}{-9^s{\cdot}83}$$

Appliquant les formules (6) pour les heures moyennes des observations, on trouve

	h m	Σ_1		Σ_2
Sept. 26	20 23	$-1{\cdot}3894$	et	$+0{\cdot}1909$
27	1 20	$-1{\cdot}4719$		$-0{\cdot}0616$

En employant la formule (7) on établira les deux équations

$$27^s{\cdot}73 = 1062{\cdot}8\ \ y - 2722{\cdot}4\ \ x$$
$$9^s{\cdot}83 = 2594\ \ y - \ 110{\cdot}6\ \ x$$

qui conduiront aux valeurs suivantes :

$$N_d = 0''{\cdot}19 \qquad L = 9^h\ 30^m \text{ E. de Cointe}$$
$$= 9^h\ 43^m \text{ E. de Paris}$$

On voit que trois observations d'une étoile, faites la même nuit, à 6^h environ d'intervalle l'une de l'autre, suffisent pour donner les deux équations nécessaires à la détermination des constantes de la nutation diurne.

L'intervalle de 6^h est celui qu'on doit employer de préférence, comme le montre la formule.

Mais j'insiste surtout sur la haute utilité qu'il y aurait à ce que les deux observations extrêmes fussent séparées exactement par un intervalle de 12^h sidérales.

Je ferai voir ultérieurement l'avantage qu'on peut retirer de ces dernières observations, voulant me borner, ici, à la recherche des constantes de la nutation diurne. Je puis pourtant, dès à présent, signaler l'utilité qu'on en peut retirer au point de vue des études sur la réfraction et sur les variations de la latitude.

Ces observations ne peuvent se faire bien complètement que pendant la saison d'hiver.

J'espère que cette note arrivera encore assez tôt à la connaissance des astronomes pour qu'ils puissent expérimenter ce procédé dans la saison actuelle, et je leur serais très reconnaissant, s'ils voulaient bien avoir l'obligeance de me communiquer les azimuts de ces étoiles qu'ils auraient observés à 12^h sidérales d'intervalle.

Au moment où je termine cette note, M. Niesten, astronome à l'Observatoire royal, me remet les résultats qu'il a déduits des observations de la Polarissime, faites à Kieff de juin à août 1879, en employant les formules que j'ai données dans ma théorie des mouvements diurne, annuel et séculaire de l'axe du monde.*

Je consigne ici ces derniers résultats, qui sont tout aussi concluants que les précédents.

Observations de la Polarissime (Kieff).

(1)	17 juin 1879	K = 0″122	L = 104°6 E. de Kieff
(2)	20 „	0·044	96·8
(3)	21 „	0·104	101·6
(4)	22 „	0·102	120·6
(5)	25 „	0·088	98·0
(6)	1 juillet	0·063	123·8
(7)	4 „	0·119	178·5
(8)	7 „	0·095	135·5
(9)	9 août	0·050	112·2
(10)	17 „	0·114	136·7
(11)	18 „	0·128	150·0
(12)	21 „	0·187	90·6
	Moyenne	K = 0·101	L = 120· E. de Kieff
			30·5
			L = 150·5 E. de Greenwich
			= 10^h.

* M. Niesten s'est servi des A.R. et des déclinaisons des observations distantes d'un certain nombre d'heures d'intervalle dans une même soirée.

The Greenwich Standard Right Ascensions for 1880·0.
By A. M. W. Downing, M.A.

The Greenwich Clock-Star List for 1889 gives the assumed mean Right Ascensions of clock stars deduced from the "Standard Mean Right Ascensions for 1880, January 1, based on 12-hour groups," printed at the end of the Introduction to the Ten-Year Catalogue. The proper motions used are taken from Auwers' "Neue Reduction der Bradley'schen Beobachtungen," for all stars except *μ Andromedæ*, for which Main's proper motion has been used as heretofore. For *δ Sculptoris* the proper motion is taken from the Cape Catalogue 1880, and is the same as that adopted in the British Association Catalogue. A comparison, therefore, of the R.A.'s of the Greenwich Clock-Star List for 1889 with those of the *Berliner Jahrbuch* for the same year will give the systematic differences between the Greenwich Standard Right Ascensions for 1880·0 and those of Auwers' *Fundamental Catalog* (from which the *Berliner Jahrbuch* places are deduced), and may be of sufficient interest to warrant its publication in the *Monthly Notices*.

The Berlin places of *μ Andromedæ* and *δ Sculptoris* have been corrected for the effect of difference in the adopted proper motions, the Greenwich values being used in both cases. The stars common to the Greenwich and Berlin lists have then been arranged in order of declination, and the differences taken. The following table exhibits the individual differences for these stars, taken in the sense Greenwich − Berlin, or correction to the *Berliner Jahrbuch*; and there are added, for comparison, columns giving the differences Greenwich 1880—*Nautical Almanac* 1889, or correction to the *Nautical Almanac*, and Greenwich 1880—Greenwich Clock-Star List for 1888 (the places of which have been brought up to 1889), or correction to the latter Clock-Star List. It will be remembered that the Right Ascensions of these stars in the *Nautical Almanac* for 1889 have been derived, practically, from the Standard Mean Right Ascensions for 1872·0, published in the Introduction to the Greenwich Nine-Year Catalogue, the adopted proper motions being those determined by Main or Stone, whilst the Right Ascensions of the Clock-Star List for 1888 have also been derived from the same Standard Mean Right Ascensions, but with the aid of Auwers' proper motions, except in the above-mentioned cases. The proper motions adopted in the *Berliner Jahrbuch* for 1889 are, of course, those of Auwers, referred to above.

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
α Lyræ	+38·7	−0·047	+0·011	+0·009
μ Andromedæ	37·9	− ·071	...	+ ·015
β Andromedæ	35·0	− ·070	− ·043	− ·031
β¹ Lyræ	33·2	− ·033	+ ·028	+ ·005
ι Aurigæ	33·0	− ·070	+ ·049	− ·013
ζ Herculis	31·8	− ·069	− ·066	− ·038
ε Herculis	31·1	− ·026	...	+ ·005
ρ Bootis	30·9	− ·027	− ·001	+ ·007
ζ Cygni	29·8	+ ·003	+ ·058	+ ·033
ε Andromedæ	28·7	− ·033	...	− ·006
β Tauri	28·5	− ·018	− ·024	+ ·006
α Andromedæ	28·5	− ·016	+ ·024	+ ·017
β Geminorum	28·3	− ·024	+ ·022	+ ·003
6 Cancri	28·1	− ·049	+ ·012	− ·035
μ Herculis	27·8	− ·073	− ·004	− ·033
32 Vulpeculæ	27·6	− ·041	+ ·015	+ ·009
ψ Bootis	27·4	− ·036	− ·034	− ·010
α Coronæ	27·1	− ·035	− ·007	+ ·002
μ Leonis	26·5	− ·036	+ ·034	− ·012
16 Pegasi	25·4	− ·033	− ·022	+ ·004
ι Pegasi	24·8	− ·016	...	− ·004
ε Leonis	24·3	− ·009	+ ·017	+ ·021
μ Pegasi	24·0	− ·016	...	+ ·003
η Tauri	23·8	− ·013	+ ·012	+ ·005
α Arietis	22·9	− ·030	+ ·027	+ ·018
τ Tauri	22·7	− ·007	...	+ ·001
μ Geminorum	22·6	− ·047	− ·057	− ·036
η Geminorum	22·5	− ·035	+ ·018	− ·017
δ Geminorum	22·2	− ·023	− ·057	+ ·003
δ Leonis	21·1	− ·016	− ·003	+ ·009
ζ Geminorum	20·7	− ·052	...	− ·035
η Cancri	20·7	− ·049	− ·002	− ·024
β Arietis	20·3	− ·033	+ ·042	− ·005
α Bootis	19·8	− ·010	+ ·015	+ ·028
γ Herculis	19·4	− ·002	+ ·002	+ ·015
δ Arietis	19·3	− ·025	− ·017	− ·004
η Bootis	19·0	− ·035	− ·035	− ·022
ε Tauri	18·9	− ·057	+ ·009	− ·025

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	
83 Cancri	+18·2	−0·023	+0·070	+0·017
τ Bootis	18·0	− ·033	− ·015	− ·004
γ Geminorum	16·5	− ·038	+ ·030	+ ·010
α Tauri	16·3	− ·012	− ·009	·000
γ Serpentis	16·0	− ·015	...	− ·006
α Delphini	15·5	− ·013	...	+ ·012
γ Tauri	15·4	− ·037	− ·020	+ ·010
β Leonis	15·2	− ·006	+ ·010	+ ·003
ε Aquilæ	14·9	− ·047	+ ·051	·000
ν Orionis	14·8	− ·047	− ·055	− ·032
η Piscium	14·8	− ·037	− ·014	− ·010
α Pegasi	14·6	− ·008	+ ·003	+ ·009
γ Pegasi	14·6	− ·042	− ·024	− ·011
α¹ Herculis	14·5	− ·030	+ ·019	+ ·002
ζ Aquilæ	13·7	− ·009	+ ·069	+ ·011
ξ Geminorum	13·0	− ·020	− ·061	− ·033
α Ophiuchi	12·6	− ·019	+ ·058	+ ·013
f Tauri	12·6	− ·041	...	− ·025
α Leonis	12·5	− ·007	+ ·025	+ ·009
α Cancri	12·3	+ ·032	+ ·072	+ ·053
ε Virginis	11·6	− ·033	− ·043	− ·023
ω Aquilæ	11·4	− ·031	+ ·019	− ·010
l Leonis	11·1	− ·043	+ ·012	− ·016
ε Delphini	10·9	− ·024	·000	− ·008
ο Leonis	10·4	− ·036	+ ·027	− ·021
γ Aquilæ	10·3	− ·019	− ·012	+ ·014
ζ Pegasi	10·3	− ·020	− ·057	− ·002
ρ Leonis	9·9	− ·047	− ·047	− ·027
κ Ophiuchi	9·5	− ·019	+ ·025	− ·006
β Cancri	9·5	− ·036	− ·031	− ·026
72 Ophiuchi	9·5	− ·011	− ·003	+ ·007
ε Pegasi	9·4	− ·032	− ·046	− ·006
ο Virginis	9·3	− ·035	...	− ·021
ο Tauri	8·6	− ·045	− ·104	− ·011
π Leonis	8·6	− ·014	− ·017	− ·001
ο Piscium	8·6	− ·023	− ·042	+ ·010
α Aquilæ	8·6	− ·026	− ·012	+ ·004
β Canis Min.	8·5	− ·032	− ·021	− ·018

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
χ Leonis	+8·0	+0·024	+0·015	+0·040
ξ^2 Ceti	8·0	− ·032	− ·001	− ·001
α Orionis	7·4	+ ·001	+ ·017	+ ·020
ε Piscium	7·3	− ·024	− ·072	+ ·014
δ Piscium	7·0	− ·035	+ ·009	·000
ε Hydræ	6·8	− ·017	+ ·009	+ ·017
α Serpentis	6·8	− ·037	− ·026	− ·005
ω Piscium	6·2	− ·029	− ·035	− ·013
β Aquilæ	6·1	− ·042	− ·046	− ·023
α Canis Min.	5·5	+ ·019	+ ·098	·000
ι Piscium	5·0	− ·032	− ·044	− ·016
ν Piscium	4·9	− ·024	+ ·023	+ ·013
α Equulei	4·8	− ·009	...	+ ·008
ε Serpentis	4·8	− ·014	− ·053	+ ·001
β Ophiuchi	4·6	− ·014	+ ·037	+ ·018
δ Virginis	4·0	·000	− ·050	+ ·014
α Ceti	3·7	− ·008	+ ·014	+ ·031
δ Aquilæ	2·9	− ·036	+ ·030	+ ·008
γ^2 Ceti	2·8	− ·041	+ ·012	+ ·020
γ Piscium	2·7	− ·001	+ ·046	+ ·017
β Virginis	2·4	+ ·022	...	+ 0·15
λ Ophiuchi	2·2	− ·026	...	+ ·007
τ Virginis	2·1	− ·021	− ·041	− ·015
κ Piscium	+0·6	+ ·001	+ ·004	+ ·019
ζ Virginis	0·0	− ·016	− ·035	− ·008
η Virginis	−0·1	− ·030	+ ·005	− ·020
υ Leonis	0·2	− ·018	+ ·024	+ ·005
δ Ceti	0·2	− ·048	...	− ·028
δ Orionis	0·4	− ·036	− ·051	− ·010
η Aquarii	0·7	− ·021	+ ·024	+ ·004
α Aquarii	0·9	− ·006	+ ·052	+ ·015
θ Aquilæ	1·2	− ·006	− ·003	+ ·014
ε Orionis	1·3	− ·005	+ ·021	+ ·017
γ Aquarii	1·9	− ·010	+ ·019	+ ·020
η Serpentis	2·9	− ·008	− ·002	+ ·013
δ Ophiuchi	3·4	− ·033	+ ·016	− ·003
μ Eridani	3·5	− ·014	− ·048	− ·010
12 Ceti	4·6	− ·050	+ ·012	− ·021

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
θ Virginis	− 4·9	+ 0·014	+ 0·010	+ 0·014
β Aquarii	6·1	− ·036	+ ·012	+ ·005
67 Ceti	6·9	− ·032	+ ·025	+ ·016
o^1 Eridani	7·1	− ·081	− ·012	− ·035
α Hydræ	8·2	− ·034	+ ·023	− ·012
λ Aquarii	8·2	− ·002	+ ·120	+ ·043
β Orionis	8·3	− ·004	+ ·010	+ ·013
θ Aquarii	8·3	− ·037	+ ·024	+ ·028
θ Ceti	8·8	− ·064	− ·021	− ·023
β Libræ	9·0	− ·028	+ ·022	+ ·005
ι Ceti	9·4	− ·012	+ ·068	+ ·019
κ Orionis	9·7	+ ·008	− ·008	+ ·019
ε Eridani	9·8	− ·021	− ·004	+ ·005
κ Virginis	9·8	− ·039	...	− ·027
ε Aquarii	9·9	− ·004	+ ·043	+ ·029
δ Eridani	10·1	− ·015	...	− ·035
ζ Ophiuchi	10·3	− ·027	− ·033	− ·002
α Virginis	10·6	− ·026	+ ·007	− ·002
θ Canis Maj.	11·9	− ·053	− ·041	− ·033
$α^2$ Capricorni	12·9	− ·008	+ ·033	+ ·013
$γ^1$ Eridani	13·8	− ·007	+ ·031	+ ·016
δ Crateris	14·2	− ·001	− ·036	− ·010
β Capricorni	15·1	− ·015	...	+ ·029
γ Canis Maj.	15·5	− ·008	− ·103	− ·033
α Libræ	15·6	− ·012	− ·035	+ ·007
η Ophiuchi	15·6	− ·006	+ ·010	+ ·023
$δ^2$ Corvi	15·9	− ·065	− ·166	− ·035
μ Hydræ	16·3	− ·038	− ·041	− ·045
δ Capricorni	16·6	− ·023	...	− ·006
β Canis Maj.	17·9	− ·036	...	− ·017
α Leporis	17·9	+ ·001	+ ·023	+ ·060
ρ Capricorni	18·2	− ·057	+ ·042	− ·015
β Ceti	18·6	− ·038	+ ·026	− ·002
$ι^1$ Libræ	19·4	− ·032	...	− ·003
$β^1$ Scorpii	19·5	− ·014	− ·012	− ·002
μ Sagittarii	21·1	− ·039	+ ·030	− ·014
ε Corvi	22·0	− ·037	− ·031	− ·015
ε Leporis	22·5	− ·050	− ·015	− ·021

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
β Corvi	−22·8	+0·043	+0·118	+0·043
15 Argûs	24·1	− ·030	− ·024	− ·017
θ Ophiuchi	24·9	+ ·005	+ ·034	+ ·025
h^2 Sagittarii	25·1	+ ·015	− ·003	+ ·003
α Scorpii	26·2	− ·041	− ·039	− ·015
δ Sculptoris	28·7	+ ·001	+ ·004	+ ·001
ϵ Canis Maj.	28·8	− ·011	− ·023	− ·006
α Piscis Aust.	−30·2	− ·014	+ ·027	+ ·003

With a view to discussing the systematic corrections to the star places of the *Berliner Jahrbuch*, the stars have been combined in convenient groups, and the means of the corrections and of the declinations corresponding to each group taken. The mean $\Delta\alpha$'s have then been graphically represented, and a curve drawn through them, from which can be read off the corrections corresponding to any declination between the extreme limits. The following table, in the columns headed I., gives the computed mean corrections and the corresponding quantities as read off from the curve. The curve has been extended, on both sides, beyond the limits of the extreme mean declinations, by making use of the corrections derived from single stars situated beyond those limits. Its course is, as will be readily understood, considerably more uncertain in these parts than it is between Dec. $+33°·9$ and $-25°·1$. The corrections, read off from this curve, have then been applied, with reversed signs, to the $\Delta\alpha$ for each star; and it is considered that the outstanding differences are those depending on R.A. The stars have therefore been arranged in order of R.A. and combined in groups of 1^h each, and by a graphical representation of the mean corrections, similar to that explained above, we obtain from the curve which has been drawn the values of $\Delta\alpha$, corresponding to the mean R.A. of each group. The resulting quantities are printed in the table of corrections depending on R.A. given below. The corrections, read off from the curve last referred to, have then been applied, with reversed signs, to the $\Delta\alpha$ for each star, arranged in order of declination, which has been used in forming the first approximation to the systematic corrections depending on declination. The residuals may be considered to be free from discordances depending on R.A., and being treated exactly as before, give the second approximation to the values of the systematic corrections depending on declination. This second approximation is given in the following table, in the columns headed II. As the second approximation differs so little from the first, it was not considered necessary to proceed to a further approximation.

Corrections depending on Declination.

Mean Dec.	Mean Δα. I.	Mean Δα. II.	No. of Stars.	Δα (from Curve). I.	Δα (from Curve). II.
°	s	s		s	s
+33·9	−0·052	−0·051	8	−0·052	−0·051
+28·0	− ·033	− ·035	11	− ·036	− ·037
+23·5	− ·023	− ·024	10	− ·028	− ·029
+19·6	− ·030	− ·031	11	− ·027	− ·028
+14·4	− ·022	− ·023	18	− ·026	− ·027
+10·0	− ·027	− ·030	20	− ·024	− ·026
+ 5·0	− ·018	− ·019	21	− ·021	− ·023
− 1·6	− ·018	− ·021	16	− ·021	− ·022
− 8·9	− ·027	− ·027	17	− ·025	− ·026
−16·2	− ·024	− ·026	17	− ·023	− ·025
−25·1	− ·016	− ·019	11	− ·016	−0·019

Corrections depending on Right Ascension.

Mean R.A.	Mean Δα.	No. of Stars.	Δα (from Curve).
h	s		s
0·4	−0·004	9	−0·003
1·5	− ·011	6	− ·009
2·5	− ·009	6	− ·007
3·5	+ ·001	7	− ·005
4·5	− ·011	7	− ·003
5·4	+ ·011	8	·000
6·5	− ·011	10	− ·001
7·6	+ ·007	5	+ ·003
8·5	+ ·007	5	+ ·006
9·5	+ ·001	6	+ ·003
10·5	+ ·002	5	+ ·006
11·5	+ ·015	6	+ ·009
12·5	+ ·001	6	+ ·006
13·6	+ ·005	6	+ ·005
14·6	+ ·006	5	+ ·005
15·6	− ·001	7	+ ·001
16·5	− ·002	8	− ·001
17·4	+ ·002	6	+ ·001
18·4	+ ·001	6	+ ·002
19·5	+ ·001	7	+ ·002
20·5	+ ·004	8	+ ·004
21·6	+ ·005	6	+ ·006
22·6	+ ·009	10	+ ·008
23·5	+ ·007	5	+ ·005

In a paper entitled "On the Star Places of the *Nautical Almanac*," printed in the *Monthly Notices*, vol. xlv. No. 5, there will be found tables giving the systematic corrections to the star places of the *Nautical Almanac*, the *Berliner Jahrbuch*, the *American Ephemeris*, and the *Connaissance des Temps*, all for the year 1883, to reduce them to the system of the *Nautical Almanac* for 1884. The star places of the *Nautical Almanac* for 1883 were derived from the Greenwich First and Second Seven-Year Catalogues, with Main's or Stone's proper motions. Those of the *Nautical Almanac* for 1884 were derived from the Greenwich Nine-Year Catalogue, using the same proper motions. The *Berliner Jahrbuch* places for 1883 were derived from Auwers' *Fundamental Catalog*, using the proper motions of that Catalogue, as were also the Berlin places for 1889, as stated above. These tables of systematic corrections, therefore, in combination with the comparison of the Greenwich R.A.'s for 1889 with those of the *Berliner Jahrbuch* for the same year, enable us to form tables of systematic corrections to the R.A.'s of the *Nautical Almanac* for 1883, the *American Ephemeris* for 1883, the *Connaissance des Temps* for 1883, and the *Nautical Almanac* for 1884, to reduce them to the system of the Greenwich Standard Right Ascensions for 1880·0.

These final tables of systematic corrections are given below. It will be noticed that, except for the considerable difference in adopted equinox,* the Greenwich Standard R.A.'s for 1880·0 approximate closely to those of the *Fundamental Catalog*—more closely, in fact, than they do to those of the *Nautical Almanacs* for 1883 or 1884; a result which appears to be due, partly, to the adoption of Auwers' proper motions in the formation of the Greenwich mean places (the effect of which can be estimated from a comparison of the corrections to the *Nautical Almanac* for 1889 with those to the Greenwich Clock Star List for 1888, given in the first table above), and partly to the gradual elimination of periodic errors from the assumed places of the Greenwich clock-stars, which is being effected by the methods now adopted at Greenwich for the determination of Standard Right Ascensions.

Corrections depending on Declination.

Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
°	s	s	s	s	s
+35·0	−0·061	−0·025	−0·082	+0·020	+0·001
30·0	− ·042	− ·017	− ·058	+ ·012	·000
25·0	− ·031	− ·020	− ·042	+ ·012	− ·010
20·0	− ·028	− ·014	− ·040	+ ·016	− ·013
15·0	− ·027	− ·006	− ·043	+ ·020	− ·012

* The difference between the equinox of the *Fundamental Catalog* and that now adopted at Greenwich is pointed out in a paper on "The Greenwich Standard Right Ascensions," published in the *Monthly Notices*, vol. xl. No. 3.

Corrections depending on Declination.

Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
°	s	s	s	s	s
+ 10·0	−0·026	−0·002	−0·046	+0·003	−0·009
+ 5·0	− ·023	·000	− ·046	− ·009	− ·010
0·0	− ·022	+ ·008	− ·042	− ·009	− ·010
− 5·0	− ·023	+ ·017	− ·039	− ·006	− ·006
10·0	− ·026	+ ·018	− ·043	− ·006	− ·008
15·0	− ·025	+ ·021	− ·044	− ·002	− ·005
20·0	− ·023	+ ·022	− ·042	− ·003	− ·002
−25·0	− ·020	+ ·024	− ·037	− ·011	+ ·006

Corrections depending on Right Ascension.

R.A.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
h	s	s	s	s	s
0·0	+0·001	+0·039	+0·003	+0·037	+0·026
1·0	− ·007	+ ·022	− ·006	+ ·022	+ ·005
2·0	− ·008	+ ·009	− ·007	+ ·009	− ·004
3·0	− ·006	·000	− ·004	− ·009	− ·004
4·0	− ·004	− ·013	·000	− ·036	− ·009
5·0	− ·002	− ·022	+ ·002	− ·053	− ·010
6·0	− ·001	− ·030	− ·001	− ·055	− ·013
7·0	·000	− ·029	− ·003	− ·042	− ·012
8·0	+ ·004	− ·009	+ ·002	− ·016	+ ·006
9·0	+ ·005	+ ·021	+ ·006	− ·004	+ ·030
10·0	+ ·005	+ ·022	+ ·009	− ·005	+ ·028
11·0	+ ·008	+ ·007	+ ·012	− ·009	+ ·011
12·0	+ ·007	− ·013	+ ·006	− ·019	− ·009
13·0	+ ·005	− ·025	+ ·001	− ·022	− ·017
14·0	+ ·005	− ·027	− ·002	− ·018	− ·011
15·0	+ ·004	− ·021	− ·004	− ·011	− ·006
16·0	·000	− ·014	− ·006	− ·003	− ·006
17·0	·000	·000	− ·001	+ ·008	− ·001
18·0	+ ·002	+ ·019	+ ·006	+ ·022	+ ·012
19·0	+ ·002	+ ·038	+ ·005	+ ·031	+ ·021
20·0	+ ·003	+ ·051	+ ·003	+ ·038	+ ·032
21·0	+ ·005	+ ·058	+ ·003	+ ·044	+ ·040
22·0	+ ·007	+ ·060	+ ·005	+ ·047	+ ·043
23·0	+ ·007	+ ·053	+ ·007	+ ·046	+ ·039

Blackheath: March 1889.

On a Graphical Method for determining the Orbit of a Binary Star. By Professor S. Glasenapp.

(*Communicated by Herbert Sadler.*)

The problem of determining the elements of a binary star consists of two separate parts: (1) to obtain the apparent orbit from a series of given observations, and (2) to compute the elements of the true orbit, the apparent orbit being given. Both parts can be solved by graphical and analytical methods.

Between the true and apparent orbit exists a geometrical relation which furnishes the means for obtaining one orbit when the other is given; this is a purely geometrical problem.

The apparent orbit is never known; we can only determine the probable apparent orbit of the component stars. Each computer tries to obtain the most probable orbit.

The general equation of an ellipse, being a curve of the second degree, is—

$$\alpha x + \beta y + \gamma x^2 + \delta xy + \epsilon y^2 + 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where x and y are the rectangular co-ordinates of the *comes* relative to the principal star which coincides with the origin of the co-ordinates. The plane of co-ordinates is perpendicular to the line of sight.

The coefficients of the equation (1) for an ellipse must satisfy the well-known conditions—

$$\left.\begin{array}{c}(\beta\delta - 2\alpha\epsilon)^2 - (\delta^2 - 4\epsilon\gamma)(\beta^2 - 4\epsilon) > 0, \\ \delta^2 - 4\epsilon\gamma < 0.\end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

I should add to them the two following:—

$$\gamma < 0 \text{ and } \epsilon < 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which represents that the principal star lies in the inner part of the ellipse—i.e. that the ellipse obtained intersects the two co-ordinate axes of x and y on opposite sides of the principal star. If the conditions (3) are not fulfilled all the parts of the ellipse lie outside the principal star. In this case, in determining the elements of the true orbit by the usual methods, we shall obtain imaginary elements.

Let us now consider a very simple method for determining the coefficients α, β, γ, δ, and ϵ of the general equation (1).

Let us assume that the apparent ellipse is drawn with such care as is generally employed in graphical methods.

If we put $y=0$. the equation (1) will be reduced to an equation of the second degree in x—

$$\alpha x + \gamma x^2 + 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

whose roots are the co-ordinates of the two points where the

apparent ellipse intersects the axis of x. These roots being x_1 and x_2, we obtain

$$\alpha = -\frac{x_1 + x_2}{x_1 x_2}; \ \gamma = \frac{1}{x_1 x_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

If, further, we put $x=0$, we obtain an analogous equation in y—

$$\beta y + \epsilon y^2 + 1 = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

whose roots are the co-ordinates of the two points where the apparent ellipse intersects the axis of y. These roots being y_1 and y_2, we obtain

$$\beta = -\frac{y_1 + y_2}{y_1 y_2} \qquad \epsilon = \frac{1}{y_1 y_2}{}^{*} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

If, therefore, we measure with compasses the co-ordinates x_1, x_2, y_1, and y_2 of the four intersecting points of the apparent ellipse with the co-ordinate axes, we obtain immediately, by means of the formulæ (5) and (7), the values of the four coefficients α, β, γ, and ϵ.

For the determination of δ we must take a fifth point. Let its co-ordinates be x_3 and y_3; then, from the general equation (1), we obtain

$$\delta = -\frac{1 + \alpha x_3 + \beta y_3 + \gamma x_3^2 + \epsilon y_3^2}{x_3 y_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

From the form of this equation we can see that the most accurate determination of δ will be obtained in the case when the divisor $x_3 y_3$ has its maximum value. It is always possible to choose, without any calculation, such a point on the apparent ellipse whose co-ordinates very nearly satisfy this condition. As a check we can take a second point on the opposite side of the apparent ellipse, and obtain a second value of δ.

The mean of both values will be more accurate and more free from accidental errors which may have been made in drawing the apparent ellipse.

It is easy to see that the calculation of the coefficients α, β, γ, δ, and ϵ by means of the formulæ (5), (7), and (8) is very simple. The results are quite independent of the errors which may occur in drawing secondary ellipses, circles, and lines. This is an advantage which is worthy of attention. Further, all the calculation can be made in 10 to 15 minutes of time.

To illustrate this method, I will here give a numerical example. I take the excellent "Handbook of Double Stars" of Edw. Crossley, F.R.A.S., Joseph Gledhill, F.R.A.S., and James M. Wilson, M.A., F.R.A.S., and select the example of a graphical determination of the orbit of *Castor*.

On Plate II., p. 116, of this "Handbook," we find the apparent ellipse of *Castor*. From this drawing we take the following co-ordinates of the four points of intersection of the apparent

* The co-ordinates y_1 and y_2, and also x_1 and x_2, must have opposite sings; therefore γ and ϵ must be negative.

ellipse with the axes of x and y. The positive end of the axis of x is directed to the north ($\theta=0°$), the positive end of the axis of y is directed to the point whose position is determined by $\theta=90°$.

We have—

$$\text{for } y=0 \qquad x_1=+111^{\text{mm}}\cdot 8 \qquad x_2=-233^{\text{mm}}\cdot 0,$$
$$\text{for } x=0 \qquad y_1=+170^{\text{mm}}\cdot 4 \qquad y_2=-115^{\text{mm}}\cdot 6,$$

whence we obtain—

$$\log\alpha=\log\left[-\frac{x_1+x_2}{x_1x_2}\right]=7\cdot 6676_n-10,\quad \log\beta=\log\left[-\frac{y_1+y_2}{y_1y_2}\right]=7\cdot 4444-10$$
$$\log\gamma=\log\left[\frac{1}{x_1x_2}\right]=5\cdot 5842_n-10,\qquad \log\epsilon=\log\left[\frac{1}{y_1y_2}\right]=5\cdot 7056_n-10.$$

To obtain δ we choose a point which is determined by the co-ordinates—

$$x_3=-200^{\text{mm}} \qquad y_3=-75^{\text{mm}},$$

which gives us—

$$\log\delta=\log\left[-\frac{1+\alpha x_3+\beta y_3+\gamma x_3^2+\epsilon y_3^2}{x_3y_3}\right]=4\cdot 8230-10.$$

To check this we take another point on the opposite side of the ellipse, whose co-ordinates are—

$$x_4=+50^{\text{mm}} \qquad y_4=+150^{\text{mm}},$$

and thus obtain a second value of $\log\delta=4\cdot 8549$. The logarithm of the mean of these two values of δ is equal to—

$$\log\delta=4\cdot 8392-10.$$

Thus we have obtained the values of the coefficients $\alpha, \beta, \gamma, \delta$, and ϵ of the equation (1).

This example is a good proof of the facility with which the coefficients α, β, γ, &c. can be obtained by the proposed method.

In investigating the true orbit I always use the very elegant formulæ of the late Russian Professor of the Imperial University at Kazan, M. Kowalsky,* which give the following relations between the elements of the true orbit and the coefficients α, β, γ, &c., of the general equation (1):—

$$\left.\begin{aligned}
&\frac{\tan^2 i}{q^2}\cdot\sin 2\Omega=\delta-\tfrac{1}{2}\alpha\beta\\
&\frac{\tan^2 i}{q^2}\cdot\cos 2\Omega=(\gamma-\epsilon)-\tfrac{1}{4}(\alpha^2-\beta^2).\\
&\frac{2}{q^2}+\frac{\tan^2 i}{q^2}=-(\gamma+\epsilon)+\tfrac{1}{4}(\alpha^2+\beta^2).\\
&e\sin\lambda=-\frac{q}{2}(\beta\cos\Omega-\alpha\sin\Omega)\cos i.\\
&e\cos\lambda=-\frac{q}{2}(\beta\sin\Omega+\alpha\cos\Omega).\\
&a=\frac{q}{1-e^2}.
\end{aligned}\right\}\quad\ldots\ldots\quad(9)$$

* These formulæ may be found in the *Proceedings of the Kazan Imp. University* for the year 1873.

where—

i is the inclination of plane of the orbit to the line of sight (plane of xy).

Ω is the position-angle of the node.

e is the eccentricity.

λ is the angle between the node and the periastron ($\pi - \Omega$).

a is the semi-axis major.

The first and second equations determine the node Ω and $\frac{\tan^2 i}{q^2}$; from the third we obtain $\frac{2}{q^2}$, and hence q and i; then the fourth and fifth equations determine e and λ, and from the last one we obtain the value of a.

The calculation of the elements by these formulæ, as may be seen, is very simple. The geometrical elements can be obtained in half an hour when α, β, γ, δ, and ϵ are given.

For example, we deduce—

$$\log \frac{\tan^2 i}{q2} . \sin 2\Omega = 5{\cdot}1264$$

$$\log \frac{\tan^2 i}{q2} . \cos 2\Omega = 4{\cdot}9464$$

$$\log \tan 2\Omega = 0{\cdot}1768$$

$$2\Omega = 56^{\circ}{\cdot}35 \qquad \Omega = 28^{\circ}{\cdot}18$$

$$\log \frac{\tan^2 i}{q2} = 5{\cdot}2060$$

Further—

$$\log \left[\frac{2}{q2} + \frac{\tan^2 i}{q2}\right] = 5{\cdot}9846$$

and hence—

$$\log \frac{2}{q2} = 5{\cdot}9055$$

$$\log q = 2{\cdot}1978$$

$$\log \tan^2 i = 9{\cdot}6015 \qquad i = 32^{\circ}{\cdot}30$$

$$\log e \sin \lambda = 9{\cdot}4911_n$$

$$\log e \cos \lambda = 9{\cdot}3420$$

$$\log \tan \lambda = 0{\cdot}1491_n \qquad \lambda = 305^{\circ}{\cdot}35$$

$$\log e = 9{\cdot}5901 \qquad e = 0{\cdot}380$$

and finally—

$$\log a = \log \frac{q}{1 - e^2} = 2{\cdot}2816 \qquad a = 184^{\mathrm{mm}}{\cdot}3$$

To convert the value of a into seconds of arc, we take from the "Handbook," on p. 113, the distances on the millimetre scale. We find there that—

$$1238^{\mathrm{mm}}{\cdot}2 = 45{\cdot}''07$$

Therefore—

$$a = 184^{mm}\cdot 3 = 6''\cdot 71.$$

Let us compare the geometrical elements of *Castor* thus obtained with those which are found by the authors of the "Handbook":—

Elements of the Handbook.	Glasenapp's Elements.
$a = 6''\cdot 67$	$a = 6''\cdot 71$
$e = 0\cdot 38$	$e = 0\cdot 38$
$\Omega = 28^\circ\cdot 25$	$\Omega = 28^\circ\cdot 18$
$i = 32\cdot 25$	$i = 32\cdot 30$
$\lambda = 305\cdot 17$	$\lambda = 305\cdot 35$

The elements T and n must be determined by one of the usual methods.

Observatory of the Imperial University,
St. Petersburg.

On the Determination of Normal Places. By Lieut-General J. F. Tennant, R.E., F.R.S.

When it is proposed to correct an approximate orbit by comparing the places deduced from it with a large number of observations, and obtain corrections to the elements by the method of least squares, each observated element of the place would produce an equation of condition. It becomes then necessary to reduce the number of these equations of condition somehow, so as to limit the amount of computation in forming normal equations.

It seems to have been the practice to compute the equation of condition for each observation, and then to take the mean of the equations corresponding to a group of observations, and use it as one equation. Now the use of normal places formed by comparing the observations themselves with an ephemeris from approximate elements is practically universal. Of course the accuracy of these normals is vital. No care in computing can produce trustworthy results unless the normals are accurate, and to make them so a considerable number of observations have to be used, which probably extend over a considerable time. The determination of normal places has been treated of in the fourth volume of Oppolzer's *Lehrbuch*, but his remarks do not seem to me to quite meet the wants of those who have not all his experience and skill to guide their steps.

The difference between the series of places computed from the approximate elements and the true ones may be expressed by a series of the form

$$a + bt^2 + ct^2 + \&c.$$

for a moderate interval of time. If t be the interval between the time for which a normal is desired and that of an observation, a will be the error of the ephemeris at the date of the normal; and the problem is to determine this with the greatest accuracy from a series of fallible places.

The date of the normal should be very near the mean of the dates of the observations employed in determining it. I shall assume that all the observations are of equal value, in which case we shall have the mean of observed errors of ephemeris

$$=a+\frac{\Sigma(t)}{n}b+\frac{\Sigma(t^2)}{n}c+\&c.$$

where n is the number of observations.* When the mean of the dates of observation is taken as that of the normal $\Sigma t = 0$ and $\Sigma(t^p)$ will be small when p is odd; also in all cases the values of b, c, &c. will rapidly decrease, so that we need never take into consideration more than three terms of the series; but it is evident that the value of c as deduced from the observations will largely depend on their errors. If the true value be insensible, then the value of a will be injuriously effected by determining c from the observations and by an amount which may be serious.

Oppolzer's suggestions practically come to these, that when the series of observations cannot be represented sufficiently by two terms of the series we should compare them with more approximate elements; or that, failing such, we should adopt a graphical construction; plot the errors as ordinates, with the time intervals as abscissæ; and, drawing an even curve through the points so as to represent their general run, use the ordinate corresponding to the date of observation as the error of ephemeris. I do not think this procedure will ever satisfy computers; if for no other reason, because the drawing of such an even curve satisfactorily requires an amount of technical skill which can only be attained by long practice; but otherwise the procedure is good, because it forces on one's mind the uncertainty of the result, which one is apt to forget when dealing with the arithmetical procedure, even if one does calculate its probable error.

I would suggest the following considerations as guides as to the use of the term involving t^2 in calculating normal places.

1st. Unless the rate of motion in one direction be rapidly changing, the use of the term involving t^2 will be objectionable.

2nd. If the course of the object in the neighbourhood of the normal place be nearly an arc of a great circle, it is highly probable that the use of the term in t^2 will be injurious.

3rd. If the course of the object be curved, then it may be dedesirable to determine c; but the first consideration will show for which element of observation it is necessary.

If the greatest accuracy be desirable, then, I think, the best plan would be to get in one of the above ways approximate errors

* Computers will readily make the necessary changes if the observations are of varying weights.

of ephemeris and get first corrections to the elements of the orbit. From these compute not only the places corresponding to the normal date, which are necessary for a further correction, but a place on each side of this, and from the differences between these places and those given by the original ephemeris deduce a value of c. If now we use this in the expression

$$a = \text{mean of errors of ephemeris} - \frac{\Sigma(t)}{n} b - \frac{\Sigma(t^2)}{n} c$$

instead of the value of c from the observations themselves, we shall get a good normal without the labour of computing an entire ephemeris and comparing it with observation.

Thus suppose we compute the place of the object for p days before and after the normal date as well as for that date, and the difference between the ephemeris and these revised places be on the three dates e_1, e_0, e_2, we may put

$$e_1 = a_1 - b_1 p + cp^2$$
$$e_0 = a_1$$
$$e_2 = a_1 + b_1 p + cp^2;$$

whence

$$\tfrac{1}{2}(e_1 + e_2) = a_1 + cp^2, \text{ and}$$
$$c = \frac{1}{p^2}\{\tfrac{1}{2}(e_1 + e_2) - e_0\}.$$

It is needless to compute b_1 and a_1 because an error in b will have little effect; and, moreover, owing to the change in the elements, b and b_1 would not probably be alike; but this value of c will be better than any value deduced directly from the observations.

Of course the corrected normal places would be used for the second correction of elements, and probably it would always suffice to ignore the value of e in getting places for the first investigation.

One advantage of this procedure would be that it would generally suffice to use three places of decimals in the equations of condition, and one less than Oppolzer uses all through the rest of the work, which, indeed, could now be carried out with the slide rule with much saving of labour.

On the Orbit of Comet I. (Sawerthal) of 1888. By Lieut-General J. F. Tennant, R.E., F.R.S.

This comet was discovered at the Cape of Good Hope on the morning of February 19, 1888, by Mr. Sawerthal of the Observatory. Observations were of course very frequent in the earlier part of its course, but fell off greatly as other new objects called for attention, though it continued visible as a faint object till the middle of August of that year.

From Mr. Tebbutt's observations on February 27, March 6, and March 14, I deduced a parabolic orbit; and by comparing this with a large number of observations I deduced normal places of the comet. Of course individually the places were not very accurate; but I believed that by multiplying the observations used I should get fair normals; and, as they came from all parts of the world and were by many observers, I should get rid of those errors which must arise from low magnifying power, difficulty of estimating the centre, and also from the centre of luminosity not always coinciding with the centre of mass.

Each normal place depends on all the published observations I could find during about a fortnight, and, in the case of the last place, observations kindly communicated by the Astronomer Royal and the Radcliffe Observer, which have been since published; some, which seemed manifestly erroneous, I rejected without any attempt at correction. As to the rest, no attempt was made to weight them. Paris mean time has been used in the calculations as most convenient for the *Connaissance des Temps*, but I have now corrected the times of perihelion passage to Greenwich time. The dates &c. of the normals are

No. 1	for Feb. 25·5	P.M.T.	depends on	38	obs.	from	Feb. $\overset{d}{18}$·6	to	Mar.	$\overset{d}{2}$·6
2	„ Mar. 18·5	„	„	37	„	„	Mar. 13·3	„	Mar.	22·7
3	„ Apr. 9·5	„	„	43	„	„	Apr. 3·6	„	Apr.	17·6
4	„ May 1·5	„	„	40	„	„	Apr. 25·6	„	May	8·6
5	„ May 24·5	„	„	28	„	„	May 17·5	„	May	31·5
6	„ June 13·0	„	„	22	„	„	June 7·4	„	June	19·5
7	„ July 7·0	„	„	18	„	„	June 27·4	„	July	16·4

After this last date I found few observations, and the faintness of the comet made me feel that no confidence could be placed in a normal at a later date.

The first points to be considered when combining into one result observations extending over so considerable a time was the law which should be considered as governing the errors of the ephemeris. Representing this by $a+bt+ct^2$, it is evident that if c be really too small to be determined by the observations, then we should be liable to injure the value of a (which is the correction of ephemeris required) by determining it; on the other hand, if its effect be omitted when really sensible, a would be similarly affected. On examining the apparent course of the comet it seemed that the first five places all lay nearly on a great circle, but that the course was markedly curved later; I therefore concluded that probably c would only require determination for the 6th and 7th places, when, too, the apparent velocity was rapidly changing. I, however, have actually determined a for each date both with and without the use of c. The places with c used I shall call the *first hypothesis*; those without c, the *second*.

The differences between the observed and computed places for each observation on one day were combined to form a mean error at the mean of the times of observation, and to this was assigned a weight equal to the number of observations, and an equation of condition formed to represent it. The solution of these equations by the method of least squares would have been troublesome. I therefore adopted the method described by Leverrier in the latter part of Art. 34, p. 136, of the first volume of the Paris *Annales*, using all the equations to form the *a* equation, and in forming the *b* &c. equations rejecting all those in which the coefficient of the unknown quantity is less than $\frac{1}{3}$ of its greatest coefficient; a procedure which saves much trouble without material loss of accuracy.

A first correction of the elements was then obtained on the first hypothesis, with the following result:—

Perihelion Passage 1888, March 17^d·002261 G.M.T.

$$\left.\begin{aligned} \Omega' &= 273^\circ\ 31'\ 25''\!\cdot\!37 \\ \pi' &= 237\ \ 14\ \ 12\cdot32 \\ \omega' &= 323\ \ 42\ \ 46\cdot95 \\ \iota' &= \ \ 37\ \ 46\ \ 03\cdot22 \end{aligned}\right\} \text{Equator and Equinox of } 1888\cdot0.$$

$$\log q = 9\cdot8443452$$
$$e = 0\cdot9958799.$$

Computing the places at the normal dates, I obtained the following system of errors:—

	$\alpha_o-\alpha_c$ 1st Hyp.	$\alpha_o-\alpha_c$ 2nd Hyp.	$\delta_o-\delta_c$ 1st Hyp.	$\delta_o-\delta_c$ 2nd Hyp.
	$''$	$''$	$''$	$''$
1	−1·6	+ 2·1	−1·8	−1·3
2	+0·6	+ 4·4	+2·2	+1·9
3	+6·1	+ 0·2	−3·3	−0·9
4	+0·4	+ 3·6	+1·3	−2·7
5	−4·9	− 2·2	−5·3	−3·3
6	−5·5	− 9·0	−2·0	−1·4
7	+7·7	+10·7	−4·2	−2·8

These results seemed to me to show that the conclusions I had drawn from the track of the comet were correct, and I proceeded to a second correction of the elements, using the errors of the second hypothesis for the first five dates, and those of the first for the 6th and 7th.

The resulting elements and their probable errors are—

Perihelion Passage, March $17^{d}\cdot001823 \pm 0^{d}\cdot000511$ G.M.T. or
March $17\ 0^{h}\ 02^{m}\ 37^{s}\cdot5 \pm 35^{s}\cdot5$ G.M.T.

$$\left.\begin{array}{ll} \Omega' = 273^{\circ}\ 31'\ 26''\cdot29 \pm 6''\cdot13 \\ \pi' = 237\ 14\ 06\cdot81 \pm 6\cdot13 \\ \omega' = 323\ 42\ 40\cdot52 \pm 8\cdot67 \\ \iota' = 37\ 45\ 59\cdot07 \pm 2\cdot83 \end{array}\right\} \text{Equator and Equinox of } 1888\cdot0.$$

$$\log q = 9\cdot8443367 \pm 0\cdot0000042$$
$$e = 0\cdot9958467 \pm 0\cdot0000438$$

or if referred to the ecliptic—

$$\left.\begin{array}{l} \Omega = 245^{\circ}\ 22'\ 56''\cdot0 \\ \pi = 245\ 18\ 26\cdot9 \\ \omega = 359\ 55\ 30\cdot9 \\ \iota = 42\ 15\ 10\cdot0 \end{array}\right\} \text{Equinox } 1888\cdot0.$$

The period of revolution is $2182\cdot3 \pm 34\cdot6$ years, and the probable error of an element of normal place is $2''\cdot20$ on a great circle; which shows that the mode of determining normals is satisfactory. All the equations of condition were considered of the same weight.

The large inclination of the orbit of this comet places it beyond the action of the outer and larger planets; but it will be seen that the perihelion and node are almost coincident; at the time of perihelion, too, the comet is only $0\cdot027$ (in parts of the Earth's mean distance from the Sun) from the orbit of *Venus*; so that if that planet had been in conjunction with the comet when in perihelion, it would have exercised on the comet a force $\frac{1}{270}$ of the solar attraction. It seems possible, therefore, that we owe this member of our system and the present form of its orbit to the action of *Venus* at some remote date.

On the Value of a Scale of Density on a Photograph.
By Captain W. de W. Abney, C.B., R.E., F.R.S.

In the last three eclipse expeditions which have been sent out from England under the auspices of the Royal Society it has fallen to my lot to have a good deal to say on the photographic arrangements, and at the last expedition to Grenada I devised a means of visually ascertaining the comparative brightness of the corona at different points in its surface. It struck me at the time how valuable it would be if, instead of eye measurements, the photographed image could be utilised, as then there would

be a record which could be measured at leisure, and no liability of flurry, which during an eclipse must to some extent always be present. What I propose to show is, how this can be done in a most simple manner by a small preliminary arrangement. I will trace the steps which gradually led me to devise the method I have adopted. There are extant a few instruments for measuring the sensitiveness of photographic plates which go by the name of Spurge's Sensitometer, and one of these is in my hands. It was nearly the first made by the inventor, and is an admirable instrument in many ways. The instrument consists of a series of small chambers side by side, with orifices pierced in the top of each, of different sizes. If the area of one orifice is designated by 1, then the area of the next to it is $2^{\frac{1}{3}}$, of the next $2^{\frac{2}{3}}$, and of the next 2, and so on. Every chamber has an orifice of twice the area of the third previous one. A plate exposed behind such a series of chambers for a fixed time to a uniformly illuminated surface evidently has at different parts of it different intensities of light acting on it, and on development will give a series of densities of deposit, varying according to the intensities of the light acting on it. What the law of density of deposit compared with intensity of light acting is I will not give here, though I have ascertained from experiment and calculation that a definite law does appear to exist, and one which will prove of value, I am led to believe. For my present purpose, however, it will be sufficient to point out the manner in which this density can be accurately measured. For this purpose all that is necessary is to place the negative in front of a condenser with a steady light some little way in rear of it, and form a magnified image of the plate on a white screen.

By placing a mirror a little to one side of such a light a patch of white light can be superposed over this image; and if a rod be placed in the beam of light coming through one of

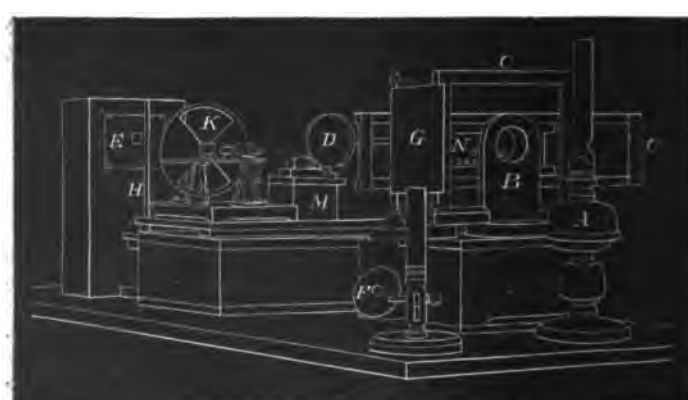


Fig. 1.

these small squares of deposit on the plate, two shadows will be thrown on the screen, one by the direct beam coming through the negative, and the other from the reflected light. The shadows will be illuminated in the ordinary Rumford photometer. A (Fig. 1) is the lamp, B the condenser, C the frame for holding the negative, D the lens which throws the magnified image, N the negative, E the receiving screen, H the rod casting the shadows, G the mirror above alluded to, K the sectors which are to be immediately described. The image of the square of deposit is bordered by a black mark to prevent the eye wandering, and the lens which throws the image is stopped down so as to make the light coming through a part of the plate on which there is no deposit rather less than one-half as bright as the reflected beam. The question is now how the shadows can be equalised. This I find most readily done by reducing the light of the reflected beam by means of rotating sectors which can be opened and closed during rotation. The following description is taken from one of my Cantor lectures recently delivered before the Society of Arts:—

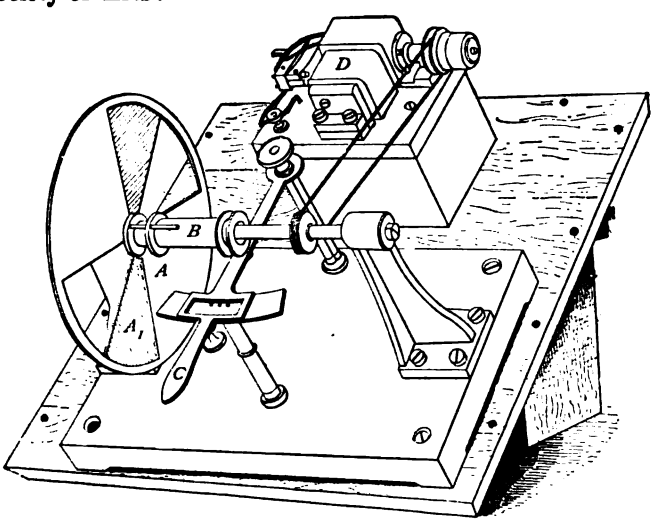


Fig. 2.

The annexed figure (Fig. 2), is a bird's-eye view of the instrument. A A are two sectors, one of which is capable of closing the open aperture by means of a lever arrangement, C, which moves a sleeve in which is fixed a pin working in a screw groove; D is an electromotor causing the sectors to rotate, and the aperture in the sectors can be opened and closed at pleasure during their revolution by means of the lever C.

Such an instrument, then, puts it in our power to equalise the shadows; and having seen what aperture of sector is required to

equalise the light passing through a portion of the plate having no deposit, the density of a deposit is measured by the ratio of the aperture required in the latter case to that of the former. Thus, if "no deposit" requires an aperture of sector of 80° to cause equality of light, and a certain deposit requires only 10°, then we know that the deposit cuts off $\frac{7}{8}$ of any light passing through it. A large number of plates exposed in the sensitometer were measured, and the results were so excellent that I went a step further. A crux in photography is to know the sensitiveness of a plate to different parts of the spectrum. This method of measurement gave a ready means of accurately doing this. A spectrum was taken on a plate in the ordinary manner, and by a comparison line-spectrum the position of the different parts of the photographed image was ascertained; but to make the matter complete it became necessary to make a scale of density on the same plate, the exposure value of the scale being known. This was effected by exposing different small parts of the unexposed portion of the plate for varying lengths of time, to a light of approximately unvarying intensity. An oil-lamp with an argand burner was found to be sufficient for the purpose. By this means, on development, we had the spectrum (in most cases that of gas-light) to be measured, a comparison spectrum of sodium and lithium, and a series of small squares of varying density, the time of exposure which gave these densities being carefully noted and recorded. This density scale was then measured in the way described, and then the spectrum was marked out in a large number of small portions, and the density of deposit of these bits carefully measured also. The image of the photographed spectrum was much enlarged on the screen, and by substituting a thick knitting-needle for the thick rod one was able to measure the average density of a very small bit of the image without any appreciable error. These measures being obtained, the relative sensitiveness of the plate to the various parts of the spectrum was readily ascertained, and could be plotted.

The scale of "density and time" was laid down on squared paper forming a curve, and then the density of deposit in the photographed spectrum was converted into its *equivalent exposure in time*, and this curve plotted. It might be objected that time of exposure and intensity of light are not interchangeable. I may say, however, that I took careful measures, and find that with the exposures given the one is convertible into the other. Here, then, we have a method of comparing the intensity of light acting on a plate solely by adding a scale as I have indicated. In the same way, by adding a scale to a photograph of the corona taken during an eclipse, a measure of the comparative intensity of light acting to form part of the image can be readily made, and can all be referred to the light of the illuminant with which the scale is made.

In the photographs of the nebulæ such as are produced by Mr. Common, if such a scale were introduced I think their value

would be very much increased, for by this artifice the relative values of the light acting at each part of the plate would be measured in a very satisfactory manner, and a record would be obtained which in time to come could be referred to to ascertain if any change in the relative brightnesses of the different parts had taken place, however small such change might be.

I give one test of the accuracy of the measurement that can be obtained by this plan. I had cut out a star of white card, (Fig. 3) in which equal distances from a fixed radius gave equal decrements of white. This star was fastened against a dead black background and rotated rapidly whilst being photographed. The photograph gave a shaded disc most dense at the centre, and nearly free from deposit at the rim. Had the black reflected no light there would have been no deposit, but as the black ground reflected 4·9 per cent. of white light this had to be taken into account. A scale was impressed on the plate as before described, and measurements of the scale and of the shaded disc

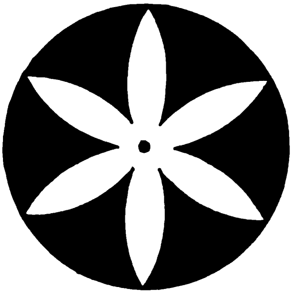


Fig. 3.

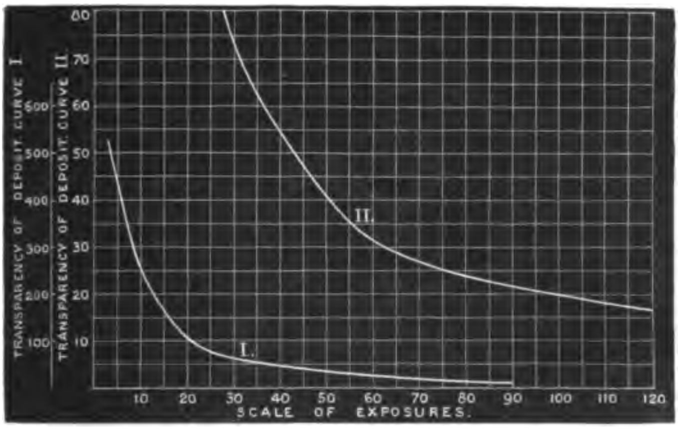
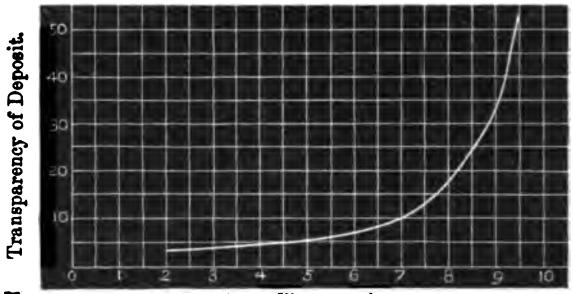


Fig. 4. Curve II. is the same as Curve I., enlarged in scale of ordinates 10 times.

made. Fig. 4 shows the density curve of the scale; Fig. 5 the density curve of the disc; whilst Fig. 6 shows the luminosity of the rotating star from calculation and from measurement. I append a table and figures to illustrate the results I obtained. It will be seen that the luminosity of the rotating star as measured from the photograph is the same as the actual luminosity, the measures lying very close to the straight line which is drawn amongst them. The small portion of light

reflected by the black surface is not sufficient to make the actual luminosity differ from a straight line on the scale to which the diagram was drawn, and may therefore be considered as prac-



Scale on Photograph.

Fig. 5.

tically a straight line. It will be noticed in Fig. 6 that the line drawn through the measured points and the line indicating the visual luminosity meet in a point, as they should

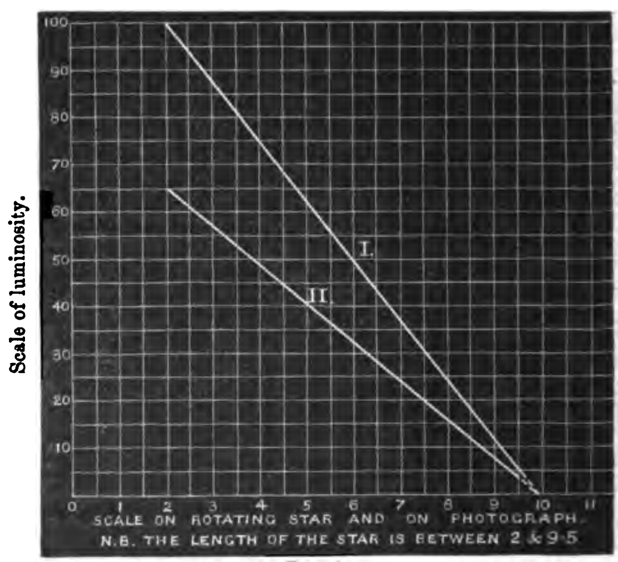


Fig. 6.

I. Luminosity of rotating star. II. Measured luminosity of photograph.

do, though beyond the limits of the star. This shows that the measured and actual luminosities are strictly proportional to one another, which of course they should be. I trust that in future work the value of attaching a density scale to each negative will be appreciated.

Distance from centre of image.	Amount of light reflected from white in %.	Amount of light reflected from black in %.	Total light reflected.	Readings of density.	Mean reading of density.	Proportion of direct light beams.	Adopted reading.	Brightness corresponding to the density from scale meas.	Brightness in %.	Remark
inches.										
·2	100	...	100	30, 31, 31	30·6	1	30·6	67	100	
·4	100	...	100	31, 31, 30	30·6	1	30·6	67	100	
·6	86·6	·6	87·3	34, 33, 34	33·6	1	33·6	58	86·6	
·8	73·3	1·3	74·6	42, 39, 41, 40	41·0	1	41·0	50	74·6	
·9	66·6	1·6	68·2	47, 47, 47	47·0	1	47·0	45	67·2	
1·0	60·0	2·0	62·0	55, 54, 53	54·0	1	54·0	40	60·0	
1·1	53·3	2·3	55·6	60, 59, 59	54·3	1	59·3	37	55·2	
1·2	46·6	2·6	49·2	67, 66, 67	67·3	1	67·6	32·5	48·5	
1·3	40·0	3·0	43·0	78, 79, 79	78·6	1	78·6	28·0	41·8	
1·4	33·3	3·3	36·6	90, 90, 89	89·6	1	89·6	24·5	36·6	
1·6	20·0	4·0	24·0	20, 20½, 21	20·5	$\frac{1}{8}$	164·6	16·0	23·9	A second set of sectors with $\frac{1}{8}$ total circle of light rotated in front of direct light.
1·7	13·3	4·3	17·6	30, 30, 31, 31	30·5	$\frac{1}{8}$	242	11·5	17·2	
1·8	6·6	4·6	11·2	40, 41, 40	40·6	$\frac{1}{8}$	324	8·0	11·9	
1·9	...	5.0	5·0	66, 66, 67	66·3	$\frac{1}{8}$	530	3·5	5·2	

Scale attached to the Photograph of the Rotating Star.

Square No.	Seconds Exposure.	Readings.	Mean Reading.	Amount of direct light on Screen.	Adopted Reading.	Remarks.
1	3	67, 67, 67	67	$\frac{1}{8}$	536	For these readings a second set of rotating sectors was placed in front of the direct light to reduce it. The direct light was thereby made only $\frac{1}{8}$ of the original light.
2	5	57, 56, 57	56·6	$\frac{1}{8}$	453	
3	10	32½, 33½, 33	33·0	$\frac{1}{8}$	264	
4	15	22, 23, 22	22·6	$\frac{1}{8}$	181	
5	20	14, 16, 15, 15	15·0	$\frac{1}{8}$	120	
6	30	8½, 9½, 9	9·0	$\frac{1}{8}$	72	
6	30	72, 71, 71	71·3	1		
7	45	47, 47, 47	47·0	1	47	
8	60	32, 33, 32½	32·5	1	32·5	
9	75	26, 25, 26	25·6	1	25·6	
10	90	23, 23½, 22½	23·0	1	23·0	
11	120	17, 17½, 18	17·5	1	17·5	

Note on the Law of Increase in Diameter of Star Discs on Stellar Photographs, with Duration of Exposure. By H. H. Turner, M.A., B.Sc.

In vol. xl. of the *Proc. Roy. Soc.*, p. 449, Professor Pritchard states that, according to his researches, the area of a star image varies nearly as the square root of the duration of exposure, or the diameter as the fourth root of the duration. He further remarks that Bond in 1858 considered the diameter to vary as the square root of the duration. It is therefore, perhaps, worthy of notice that, in some photographs taken at Greenwich with a Dallmeyer object-glass of 4 inches aperture and 5-foot focus, the diameter of the images seems to vary nearly as the cube root of the duration of exposure through a considerable range—a result intermediate between those of Bond and Pritchard. The following measures of the diameters of star-discs on different plates illustrate this point. The diameters are divided by the square roots, the cube roots, and the fourth roots of the durations, to exhibit the relative merits of the three hypotheses in question. It will be seen that the numbers in the cube-root column are generally nearly constant, while those in the other two decrease or increase. The numbers attached to the plates are merely those of the Greenwich series, for convenience of reference.

Plate 18. Region near *α Aquilæ*. 1887, August 31. Four exposures of 1^m, 5^m, 10^m, and 20^m, at the corners of a square.

Three bright stars. (Mean of magnitudes about 3.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=$D.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
1	23·0	23·0	23·0	23·0
5	38·3	17·1	22·4	25·5
10	50·5	16·0	23·5	28·4
20	64·0	14·3	23·6	30·3

Four medium stars. (Mean of magnitudes about 6.)

1	5·4	5·4	5·4	5·4
5	8·4	3·8	4·9	5·6
10	13·0	4·1	6·1	7·3
20	15·7	3·5	5·8	7·4

Six faint stars. (Mean magnitude 7 or 8.)

The short exposure not registered.

1	—	—	—	—
5	6·8	3·1	4·0	4·5
10	9·2	2·9	4·3	5·2
20	13·2	3·0	4·9	6·3

Plate 22. Region near γ *Piscium.* 1887, October 22. Four exposures of 1^m, 5^m, 10^m, 20^m, at corners of a square. "Sky tolerably good."

Five stars. (Mean magnitude about $4\frac{1}{2}$.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=$D.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
1	8·1	8·1	8·1	8·1
5	12·7	5·7	7·4	8·5
10	15·8	5·0	7·4	8·9
20	18·6	4·2	6·9	8·8

Plate No. 23. *Pleiades.* 1887, October 14. Three exposures of 2^m, 4^m, 15^m. "Sky very clear."

Five stars. (Mean magnitude about 4.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=$D.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
2	23·2	16·5	18·4	19·5
4	29·4	14·7	18·5	20·9
15	42·4	11·0	17·2	21·5

Five stars. (Mean magnitude about 6.)

2	8·9	6·3	7·1	7·5
4	10·8	5·4	6 8	7·7
15	18·9	4·9	7·7	9·6

Plate No. 87. Region near R.A. $19^h\ 14^m$, Dec. $+20°$. 1888, September 19. Exposures, 1^m, 2^m, 3^m, 5^m.

Seven stars. (Mean magnitude about 6.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=$D.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	"	"	"	"
1	7·6	7·6	7·6	7·6
2	9·2	6·5	7·3	7·7
3	10·8	6·2	7·5	8·2
5	12·2	5·5	7·1	8·1

In the above plates no particular attention was paid to the exact duration of exposure, which may thus be slightly inaccurate, especially in the case of short exposures; and the range of duration does not extend below 1^m. On 1889, March 6, special photographs of *Procyon* were taken, with exposures varying from 5^s to 20^m; but there was much haze in the sky, and often cloud, which interfered with the work. On the first plate exposures of 5^s, 10^s, 15^s, 30^s, and 60^s were secured before clouds came up; and, as it was not possible to resume operations for some time, a second plate was put in. On this exposures of 20^m, 5^s, 10^m, and 15^s were given in this order, before the work was quite stopped by clouds. On development, the exposure of 5^s on this plate was found to have been accidentally distributed into two of nearly equal size. It has been assumed that each of these was roughly $2\frac{1}{2}^s$, though some time must have been lost in transition, and allowance must be made accordingly. The following are the results of four independent measures, by each of two observers, of the various discs of *Procyon* on these two plates:—

First Plate.

Duration of Exposure $=t$.	Mean Diameter of Discs $=$D.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	"	"	"	"
0·083	18·6	64·4	42·6	34·6
·167	23·5	57·6	42·7	36·8
·250	29·3	58·6	46·6	41·5
·5	33·6	47·5	42·4	40·0
1·0	40·8	40·8	40·8	40·8

The 15^s exposure is very irregular in shape, and obviously anomalous.

Second Plate.

Duration of Exposure $=t$.	Mean Diameter of Discs $=$D.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	"	"	"	"
0·042	9·9	48·3	28·5	22·0
·042	10·8	52·7	30·9	24·0
·25	20·7	41·4	32·9	29·3
10·0	59·1	18·7	27·5	33·2
20·0	63·5	14·2	23·4	30·1

It thus appears that for large star discs the increase of diameter does not increase quite so rapidly as the cube root of the duration, and tends towards the fourth root. For faint stars, on the other hand (as in the third set of plate 18), the rapidity surpasses the cube root, and tends to the square root. This suggests how both Bond's and Pritchard's results may be true under different circumstances.

Photographic Analyses of the Great Nebula M 42 *and* 43 *and h* 1180 *in Orion.* By Isaac Roberts.

By the term photographic analyses is to be understood the appearances which this nebula presents with exposures of the negatives varying between 5 seconds of time and 205 minutes, and when the details are studied by aid of the gradations of the nebulosity which have been obtained in this manner we are enabled to compare the relative actinic power of the light in different parts of the nebula.

We are not to infer that any given exposure of a plate for, say, 15 minutes, or for any other number of minutes, represents a constant quantity of photographic effect which is always available for accurate comparison with other exposures during corresponding intervals of time, for it is found that the photographic effect generally varies from moment to moment during any exposure of a plate owing to atmospheric absorption or extinction of the light; but by taking a number of photographs and selecting them so as to exhibit small gradations in the density of the nebulosity, we see more of the structure than we probably can by any other method, and this applies with greater force to enlargements than to the original negatives.

In the illustrations now presented,* gradations are shown on seven enlarged photographic plates with eleven exposures of the negatives. The enlargements are to five times the size of the negatives.

Plate I.

The negative of which this plate is an enlargement was taken on February 16, 1889, and has upon it five consecutive exposures of 5 seconds, 30 seconds, 1 minute, 3 minutes, and 6 minutes respectively, and they show such of the stars and so much of the nebulosity as on that occasion were imprinted on the film. The four stars which form the trapezium are shown on the first exposure of 5 seconds, and they increase in diameter and in density till in the fifth exposure of 6 minutes they form one image with an irregular outline. The nebulosity begins to appear round θ in the third exposure of 1 minute, and in the 6 minutes' exposure it is well developed and characteristic. It will

* The photographs are placed in the Library.

be observed when the photographs are compared with the drawings of this nebula by Lord Rosse that there are many points of resemblance between them in the outlines as well as in the distribution of the nebulosity, and it is apparent that great care and skill have been exercised in the observing and in the drawing of the details which occupied, as Lord Rosse informs us, "every available hour during the winter months of seven seasons." When the photographic plates are exposed for 15 minutes and upwards these resemblances more or less disappear in the cumulative density of the nebulosity.

PLATES 2, 3, and 4.

These three plates were enlarged from negatives taken one on each of the following dates: February 16, 1889, December 18, 1886, and February 20, 1889, with 15 minutes' exposures, and they illustrate the differences in the density of the nebulosity due chiefly to atmospheric causes at the time of exposure.

On comparing these photographs with the well-known photograph taken by Mr. Common, on January 30, 1883, I have not detected by eye observations that any changes in the structure of the nebula have taken place during the interval of six years that has elapsed between them, but the examination should be more carefully made by measurements before full reliance is placed on this statement. It is obvious, if we compare the positions of the stars within the nebula as they are shown on the charts by Lord Rosse and by Bond, that changes in the relative positions of some of them have taken place since the year 1866, and I shall here just refer to one as an illustration. In the trapezium the two stars numbered 65 and 69 on Lord Rosse's chart are shown much closer to each other than the stars numbered 67 and 73, and Bond's chart agrees with Lord Rosse's, whereas in the photographs these pairs are nearly equidistant.

PLATES 5 and 6.

The negative of plate 5 was taken on February 18, 1889, with an exposure of 30 minutes, and that of plate 6 on December 24, 1888, with an exposure of 81 minutes. Both photographs show great extensions of the nebula, and M 43 is joined to M 42; *h* 1180 is also well developed with its characteristic dark cross streams.

PLATE 7.

The negative was taken on February 4, 1889, with an exposure of 205 minutes, and supplies us with evidence that M 42 and 43 and *h* 1180 form one gigantic nebula. The links joining *h* 1180 with the other portions are shown also on another negative which I took with two exposures upon it, one on January 22, 1889, and the other on February 3. The exposures were of

2 hours and $2\frac{1}{2}$ hours respectively. The evidence and confirmation place it beyond reasonable doubt that the links shown are realities, and though they supply us with vastly extended knowledge of the dimensions, and form, and details of this nebula, yet leave us with unsatisfied desire to see more, and probably to find that the nebula will be shown to have a symmetrical form in external outline, but is in a state of strong internal commotion. Next year we ought to be able to supply the missing links and see it as a finished picture. In the meantime we ought, with all gratitude, to admire the patient, long-suffering endurance of those martyrs to science, who during the freezing nights of many successive winters plotted, with pencil in benumbed fingers, the crude outlines which have been handed down to us as correct drawings of this wonderful nebula, which we can now depict during four hours of clear sky with far greater accuracy than is possible by the best hand-work in a lifetime.

Note on an Apparatus for correcting the Driving of the Motor Clocks of large Equatorials for long Photographic Exposures. By A. A. Common, F.R.S.

In giving long exposures in astronomical photography it is absolutely essential that some means be adopted to prevent any shift of the image on the photographic plate during exposure; for if irregularities in clock-driving, changes due to flexure of instrument, and alterations in apparent position due to refraction are not immediately corrected the photograph will be blurred and the fine detail lost. These irregularities are further complicated in the case of reflectors by changes due to alterations of temperature, and by variations of strains in the mirror as the telescope moves round.

There are obviously two methods by which the image of the object to be photographed can be kept in exactly the same position on the plate during exposure: either the telescope itself must be moved by means of its fine screws for slow motion in right ascension and declination, or the photographic plate must be moved during the exposure. The first method has been adopted by the Paris Conference for the instruments to be used in charting the stars. A finder of 9 inches' aperture is to be attached to each photographic instrument, the optic axes to be parallel; and the stars are to be watched throughout the exposure and any shift immediately checked by the slow-motion screws of the instrument. For small instruments this method is perhaps capable of meeting all the difficulties, for the slow motions can be made to work smoothly; but it is impossible to apply it properly to large and heavy instruments, especially to large reflectors where the parallelism of the finder and the axis of the mirror can never be rigidly maintained.

At the meeting of the Society in November 1884 I briefly referred to the apparatus used with the 3-foot reflector at Ealing for moving the photographic plate during exposure, so as to correct for shift; and a similar arrangement having been made for the 5-foot, a description of that in considerable detail is given here.

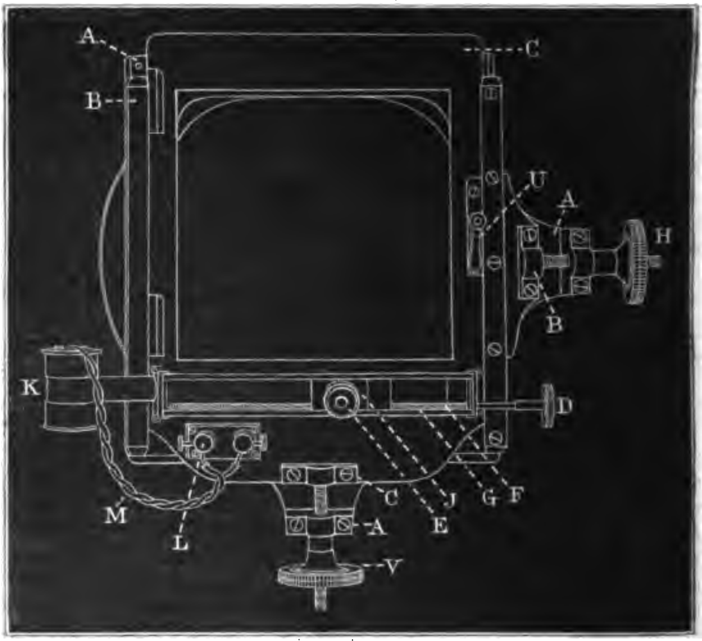


Fig. 1.

Fig. 1 is from a photograph of the apparatus with the plate-carrier detached.

A A A is a plate with three clips behind to attach it rigidly to the eye end of the telescope.

B B is a slide fitting into A and capable of movement in a horizontal direction by means of the fine screw at H.

C C is a slide falling into B and capable of movement in a direction at right angles to the movement of B by means of the fine screw at V.

The dark slide is fitted on to the plate C, a small cam, U, serving to fix the dark slide in position. D is the milled head of a fine screw, F, extending the whole length of the box G, the latter being part of the slide C, and having a glass face.

The plate J slides in grooves above the glass face, and has the eyepiece E screwed into it.

On F is fitted a nut, carrying a small ring (under the glass face) with two cross-wires, the intersection of which is exactly

in the focus of E, and also in the plane of the film of the photographic plate. The cross-wires are illuminated from the side by a small incandescent lamp in K, the light being steady and uniform when the current is supplied from one or two storage cells to the screws L and thence through M to the lamp.

Any one of a line of small pinholes through the bottom of the box G can be uncovered by bringing the cross-wires and eyepiece directly over it. Unless the uncovered pinhole is very small there will be danger of light getting through it and on to the photographic plate, the faintest external light falling on the plate for two or three hours being sufficient to fog it.

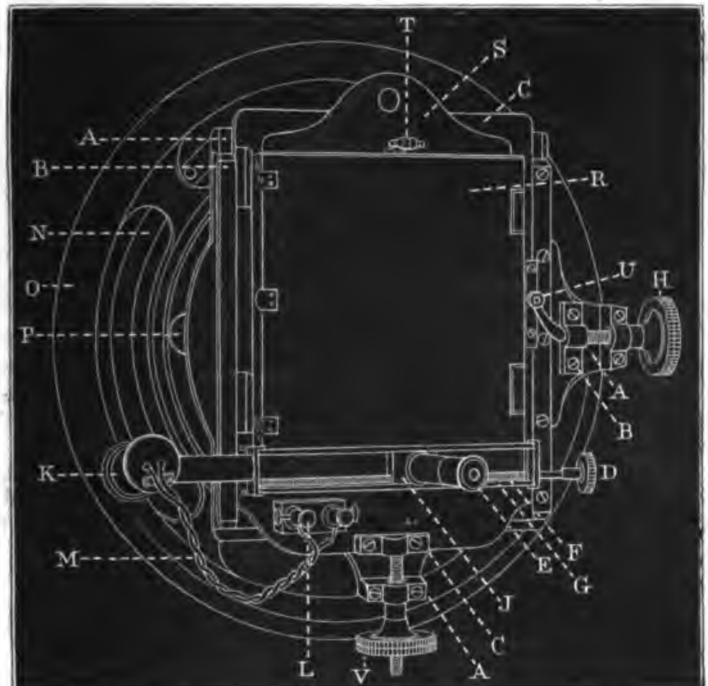


Fig. 2.

Fig. 2 shows the whole eyepiece end of the telescope with the dark slide in position ready for exposure of the plate.

R is the dark slide fitting on to C and fixed to it by U, S is the shutter of ebonite, and T is a small screw which serves to hold the shutter down when the slide is closed, as in figure. and holds it open when the plate is being exposed. N is a ring screwed to the end of the reflector. O is the focussing-wheel, and P one of the three levelling-screws for getting the plate a right angles to the optic axis of the mirror.

In practice, before the exposure is commenced, the apparatus is arranged so that the screw H gives a motion in R.A. to the plate, and V a motion in declination; then any star on the edge of the field is fixed upon and the cross-wires brought directly over it. Throughout the exposure this star is kept under view; the eyepiece being very powerful, the smallest errors become apparent to the eye, and can be corrected at once by the screws. If from any cause it is necessary to discontinue the exposure the plate can be shut up, and the exposure can be recontinued at any time if the guiding star is brought exactly to the cross-wires, for then the plate is in the same position as it was before the interruption. The wires being in exactly the same plane as the film, any alteration of focus can be at once detected in the eyepiece and corrected at once by the focussing-wheel.

Spectroscopic Observations of sundry Stars and Comets, made at the Royal Observatory, Greenwich, chiefly in the years 1887 *and* 1888. By E. W. Maunder.

(*Communicated by the Astronomer Royal.*)

I. γ Cassiopeiæ and β Lyræ.

The object of the following observations was to detect any bright lines in the spectra of these two stars, to watch if such lines varied in brightness, and to determine the wave-length of the bright line near the D lines, supposed to be D_3.

The instruments employed were the half-prism spectroscope, with one half-prism, either in the direct or reversed position, and the single-prism spectroscope, with one large prism of 60°. The dispersions of the three instruments are as follows:—

	A to H.	Power of Eyepiece.
	°	
Half-prism spectroscope, Direct	18½	14
,, ,, Reversed	5	30
Single-prism spectroscope	4⅔	10

These were mounted on the South-East equatorial, of 12·8 inches' aperture, and were used either with or without a cylindrical lens before the slit.

γ *Cassiopeiæ.*

Single-prism spectroscope.

Three bright lines were observed, viz. C, F, and a line near D, supposed to be D_3. These three lines, if seen at all, were seen as bright lines, never as dark.

Date.	Cylindrical Lens before slit. C	D_3	F
1887, Feb. 16	Not seen	Not seen	Very distinct
Dec. 5	*Brilliant*	Not seen	Faint
16	Not seen	Not seen	Faint
1888, Sept. 19	Very bright	Faint	Rather faint

	No Cylindrical Lens. C	D_3	F
1887, Feb. 16	Not seen	Not seen	Very distinct
Dec. 5	*Brilliant*	Not seen	Faint
16	Distinctly seen	Not seen	Not seen
1888, Sept. 19	Very bright	Faint	Rather faint

Half-prism spectroscope, direct. Cylindrical lens before slit.

The C and D_3 lines were not looked for. The F line was observed as follows:—

Date.	Description of Bright F line.
1880, Oct. 1	Brilliant against the background of the continuous spectrum. Broad and diffused at edges. Central condensation.
Nov. 21	Bright.
1881, Dec. 7	Difficult to measure.
1883, Nov. 16	Easily seen.
1884, Aug. 11	Faint.
25	Faint.
Sept. 4	Very faint.
10	Barely visible.
11	Measured. No remarks made.
18	Very faint.
20	Faint. Sharp; well-defined at edges.
1887, Feb. 16	Very faint. Narrow.
Oct. 19	Distinctly a bright line. Broad, and diffused at edges.
1888, Dec. 13	Faint. Narrow, and slightly diffused at edges.

Half-prism spectroscope, reversed. Both with and without a cylindrical lens before the slit.

1887, Dec. 16. Observations made with single-prism spectroscope confirmed.

β Lyræ.

The same three lines—viz. C, D_3, and F—were observed as in the spectrum of *γ Cassiopeiæ*. D_3 was always seen as a bright line if seen at all, but C and F were on one occasion—1888, October 19—suspected to be represented by dark lines.

Half-prism spectroscope, reversed.

Date. 1887.	Cylindrical Lens before slit. C	D_3	F	No Cylindrical Lens. C	D_3	F
Dec. 16	Not seen	Not seen	Not seen	? Bright	Not seen	Not seen

Single-prism spectroscope.

1888.						
Aug. 10	Not seen	Not seen	Not seen	Not seen	Fairly bright	Very faint
Sept. 10	...	...	...	Not seen	Faint	Not seen
19	...	...	...	Not seen	Bright	Not seen
21	Not seen	Very bright	Bright	Bright	Very bright	Bright
Oct. 19	...	...	...	? Dark line	Very faint	? Dark line

The appearance of the three lines as seen on 1888, September 21, was as follows:—

C—Narrow and sharp.

D_3—Very bright, narrow, sharp, and well defined.

F—Rather brighter than C, not nearly so bright as D_3, and somewhat ill-defined at the edges.

The D_3 line, on each occasion when it was seen, appeared to be narrow, sharp, and well-defined.

The following results were obtained for the wave-length of the bright line supposed to be D_3, by measurement of its distance from the D lines as given by a sodium flame:—

Wave-length inferred for the bright line near D.

	1888, Aug. 10; tenth-metres.		1888, Sept. 19; tenth-metres.
	5874·46		5875·76
	5·70		5·82
	3·10		4·58
	1·55		0·80
	3·59		2·79
	6·07		4·65
	5·64		6·88
	2·17		3·16
	3·34		6·13
	3·59		5·33
Mean	5873·92	Mean	5874·59
		Mean of all the measures	5874·26

General Remarks on the Spectra of γ Cassiopeiæ and β Lyræ.

The foregoing observations appear to show that—

(1) The spectra of both stars show bright lines.

(2) These bright lines are variable in brightness.

(3) In the case of γ *Cassiopeiæ*, the three bright lines observed do not vary simultaneously and in the same manner.

(4) In the case of β *Lyræ*, the observations are not sufficient to establish any conclusion, but are not inconsistent with a simultaneous variation of all the three lines observed.

(5) Two of the three lines observed are the C and F lines—the first and second lines, that is, of hydrogen. The measures made of the position of the bright line near D in the spectrum of β *Lyræ* point to its being the so-called "helium" line D_3, and not the fluting of manganese at λ 5869. Its appearance—that of a narrow, sharp, well-defined line—also agrees with this view.

(6) The observations in the case of β *Lyræ* are not sufficient to prove that the variations in the brightness of the D_3 line take place in a similar period to that of the variations in the brightness of the star itself, but they are not inconsistent with such a relation. Arranging the observations in order of the observed brightness of the D_3 line, the following table shows the interval from the next preceding chief minimum :—

Character of D_3.	Date of Observation.	h	Interval after the last Chief Minimum. d	h
Very bright	1888, Sept. 21	20	7	11
Bright	19	21	5	11
Fairly bright	Aug. 10	22	4	6
Faint	Sept. 10	21	9	9
Very faint	Oct. 19	20	9	14
Not seen	1887, Dec. 16	21	11	17

As the secondary minimum falls $6^d\ 11^h$ after the chief minimum, and the maximum following the secondary minimum about $9^d\ 16\frac{1}{2}^h$ after the chief minimum, the observations are not inconsistent with a maximum brightness of the D_3 line soon after the secondary minimum of the star, followed by a decline to a minimum soon after the second maximum of the star.

(7) The D_3 line is the most conspicuous bright line in the spectrum of β *Lyræ*, but either C or F is the most conspicuous in that of γ *Cassiopeiæ*.

II. Stars with Spectra of the Third Type (Secchi's).

o Ceti (Mira) near Maximum.

1888, *October* 5.—The spectrum of the star had a remarkably clean appearance, the "zones," or bright interspaces between the dark shaded bands, being quite free from absorption lines. Bands I., V., VII., and VIII. (Dunér's numeration) were very distinct, and all were sharp towards the violet, and shaded towards the red. Band IV. was faint, but appeared to be of the

same character as those just mentioned. Band III. was, as usual, a little shaded at *both* edges and darkest in the middle, but more nearly of a uniform shade than any of the other bands. Band IX. was found to be a rather puzzling object. Being far in the blue, it was a little difficult to make out, but it seemed at times to have its edge about 33 tenth-metres nearer to the red than at others, or at λ 4797 instead of λ 4764. Probably it consisted of two bands close together. Band IX. was faint. Bands VII. and VIII. were the darkest in the spectrum. Beyond Band VIII., towards the violet, the bands were most difficult to see, as they were so faint; but the continuous spectrum itself could be traced an unusually great distance into the violet. The violet end was very free from selective or general absorption. Bright lines at or near F and D_3 were carefully looked for, but none were seen. But a bright line in the violet, evidently the third line of hydrogen, was very distinctly seen, and several measures were obtained of its position, as follow:—

Tenth-metres.		Tenth-metres.
4346		4345
4344		4342
4343		4343
4343		4345
4342	Mean	4343·4
4341		

1888, *December* 1.—The dark bands in the spectrum of *Mira* were of intense blackness, as if slices had been cut clean out of the spectrum; Bands VII., VIII., and IX. being especially broad and black; Band VIII. the broadest and blackest of all. They seemed as if a little further expansion would make them swallow up the whole of this portion of the spectrum. The bands were less intensely marked as the red end of the spectrum was approached; the red and yellow portions of the spectrum were faint, and perhaps the bands in those districts were less easily seen on that account. The D lines could not be identified, nor could some faint bands close to D on the more refrangible side, which had been noticed the same evening in the spectrum of β *Pegasi*, be detected in this spectrum. On the other hand, a faint band, not seen in β *Pegasi*, was observed in *Mira*, below D towards the red.

Positions of the Dark Bands in Stellar Spectra of the Third Type (Secchi's).

No. of Band, Dunér's Numeration.	α Orionis. 1876, Jan. 28.	1876, Feb. 29.	1887, Dec. 16.	β Pegasi. 1876, Oct. 18.	1876, Nov. 29.	ρ Persei. 1876, Oct. 18.	α Herculis. 1877, May 7.	1877, June 4.	1877, July 2.	1888, May 2.	Mira, o Ceti 1888, Oct. 5.	Mean.
Band I.	...	6482 ±	6540 ±	...	...	...	6560 ±	...	6600 ±	...	6587 ±	6554 ±
Band II.	6198	6146	6173	6169	6168	6153	6161	...	6152	6153	6153	6163
A faint band	...	6050	...	...	...	...	...	...	...	...	...	6050
Band III.	5863	5850	5859	5869	5870	5866	...	...	5861	5865	5842	5861
A second edge to Band III.	...	...	5822	5830	...	...	5825	...	5824	...	...	5825
A faint band	5741	...	5779	5750	...	...	...	...	...	...	...	5757
Band IV.	...	5563	5577	5610	5610	5608	5608	...	5620	5592	5606	5599
Band V.	5459	5446	5445	5450	5446	5445	5445	5448	5456	5452	5448	5449
Band VI.	5251	5251	...	5272	...	...	...	...	...	...	...	5258
Band VII.	5165	5165	5164	5164	5167	5160	5169	5169	5169	5167	5171	5166
Band VIII.	4951	4951	4954	4953	4956	4950	4963	...	4956	4960	4956	4955
Band IX.	4758	4761	4780	4761	...	4752	4759	...	4771	4776	4764	4765
Band X.	...	...	4603	4595	...	4641 ±	...	...	4567	4609	...	4602
Band XI.	4446 ±	...	...	4360 ±	...	4359 ±	...	...	...	...	...	4388 ±

The above determinations of the wave-lengths of the less refrangible edges of the dark bands in stellar spectra of the third type (Secchi's) were made with micrometer B of the single-prism spectroscope, measures of the position of the D lines, as given by a sodium flame, being made on each occasion for index error. The measures of the stellar bands, after correction for index error, have been converted into wave-lengths by reference to a curve connecting micrometer readings and wave-lengths, and laid down from a series of measures of the principal lines in the solar spectrum made with the same instrument.

III. P and R Cygni.

The object of these observations was the detection and measurement of bright lines in the spectra of the two stars.

R Cygni.

R Cygni was observed on 1888, September 21 and October 1. On the former occasion bright lines were observed near D_3 and F, but, a mist rising, the star was lost before any measures could be obtained. On October 1 only the F line was seen as bright, and its position was measured once, the resulting wave-length being

Tenth-metres

4866.

The general spectrum of the star, apart from the bright line at F, appeared to be that of Secchi's fourth type—viz. one crossed by shaded dark bands, which are sharp and dark on their less refrangible side and shade off towards the violet.

P Cygni.

P Cygni was observed on 1888, October 1, and the following measures were obtained for the position of a bright line in its spectrum:—

Tenth-metres.		Tenth-metres.
4861		4860
4859		4858
4859		4852
4862		4853
4860	Mean	4858·4
4860		

The bright line, which appeared a little diffused at the edges, was observed without much difficulty. No other bright lines were detected, and, no cylindrical lens being used, no dark bands could be made out.

The single-prism spectroscope was used both for *R* and *P Cygni*, and no cylindrical lens was employed. The D lines, as given by a sodium flame, were used as a reference spectrum for index error, as in the measures given in Section II.

IV. Comets 1888 *a* and 1888 *e*.

These two comets were observed with the single-prism spectroscope, without a cylindrical lens.

Comet 1888 *a* (*Sawerthal*)

was observed on 1888, April 10, 19, and May 3. The spectrum was almost wholly continuous, but on April 19 two very feeble bright bands were detected, nearly, if not quite, coincident with the bands in the green and yellow of the spectrum of the Bunsen flame. In the case of the band in the green a direct comparison was made between the two spectra, which left no doubt of their coincidence. The third carbon band—that in the blue—was not quite satisfactorily made out, but its presence was suspected as a slight local brightening of the continuous spectrum. On May 3 no trace of the yellow and blue bands could be detected in the spectrum of the comet, and the presence of the green band was only very faintly suspected. The spectrum of the comet was practically wholly continuous. It ended rather abruptly at or near D.

The spectrum of the tail was followed to a considerable distance from the nucleus, but it differed from that of the nucleus only in its greater faintness.

Comet 1888 *e* (*Barnard* 1888, *September* 2)

was observed on 1888, November 27. The spectrum was almost wholly continuous. By carefully narrowing the slit it became possible to see that there was a local, ill-defined brightening, corresponding nearly to the green carbon band, but apparently further towards the blue. On narrowing the slit further this brightening was lost, and only the continuous spectrum was seen. This was noted only for the nucleus and its immediate neighbourhood, the fainter outlying portions of the coma not being bright enough to give a perceptible spectrum with the slit as now narrowed. On the whole, the evidence for anything beyond a purely continuous spectrum was but small; the hydrocarbon spectrum was evidently quite an unimportant and subordinate feature.

Note on the Spectrum of the Great Nebula in Orion. By E. W. Maunder.

As I have recently been informed that an observation of mine of the brightest line in the spectrum of the Great Nebula in *Orion* has been somewhat misunderstood, it being supposed, as I am told, that I had claimed to have seen this line as distinctly a fluted band, I have thought it would be well if I explained it to the Society.

The observation in question was made on February 18, 1884, in the course of my usual work of the measurement of the displacement of the lines in stellar spectra. I was using the half-prism spectroscope in the direct position on the South-East equatorial of 12·8 inches aperture, and I had endeavoured, not very successfully, to measure the displacement of the bright F line in the spectrum of the nebula, using for the purpose a dispersion of one "half-prism." I then turned to the line of the nebular spectrum near λ 5005, and found this very much brighter than the F line. It had occurred to me, as this line in the nebular spectrum had sometimes been supposed to be due to nitrogen, the spectrum of which shows a very bright pair of lines at this place, that it would be well to ascertain if the nebular line could be divided, so I put in a second "half-prism," and examined the line at λ 5005 again The dispersion now used was equivalent to that of sixteen flint prisms of 60°, or about 80° from A to H. The two nitrogen lines were widely separated, and though differing in wave-length only by three tenth-metres, their angular separation was 7′, or more than two revolutions of the eyepiece micrometer (one hundred revolutions to the inch). The slit was very narrow, about 0″·5 of arc, or $\frac{1}{2000}$ inch, and the spectroscope had been very carefully focussed during the day on the same part of the solar spectrum, and with the same dispersion. With this dispersion and slit the three principal lines of the nebular spectrum, viz. F, λ 5005, and the bright line between them, were seen as very narrow bright lines. But none of the three nebular lines were perfectly sharp; each showed a slight raggedness at both edges; but in the case of the line near λ 5005 it was clear that this fringe or raggedness was more developed towards the blue than towards the red. In the original record of the observation published in the Greenwich Observations for 1884, my note reads as follows:—"None of the lines in the spectrum of the nebula are, however, very sharp. λ 5005 showed a faint fringe mainly on the side nearer the blue." In the case of the two other lines, they were not bright enough for it to be possible to ascertain whether the fringes were symmetrical or not.

But λ 5005 was clearly a single line. There was no trace of any bright line or series of bright lines close to it on either side; no trace of a fluting properly so-called. The entire line, fringes and all, was only a fraction of a tenth-metre in total breadth; all that was remarked about it was:—

(1) That it was a single, not a double, line.

(2) That it was not quite sharp at either edge.

(3) That it was more shaded on the more refrangible edge than on the less refrangible.

The power of the eyepiece used was 14 on a viewing-telescope of 10·5 inches focal length.

The observation therefore does not afford any strong confirmation of Mr. Lockyer's view that this line in the spectrum of nebulæ is due to the fluting of magnesium, but at the same time it is not absolutely inconsistent with it.

Observations of the Planet Iris and Comparison Stars, made with the Meridian Circle at Dunsink. By Arthur A. Rambaut, M.A., Assistant Astronomer at Dunsink Observatory.

(*Communicated by Sir R. S. Ball.*)

Early in September 1888, we received from Dr. Gill a list of twenty-eight stars, which he proposed to use as comparison stars for a determination of the parallax of the planet *Iris*, with a request that we should determine their places with our meridian circle, and that we should at the same time procure as many meridian observations as possible of the planet.

This work was commenced at once on receipt of Dr. Gill's communication, but owing to the unfavourable state of the weather the list, to which two stars were added during the progress of the work, was not completed till January 10 of this year.

The places of the stars given below are strictly differential, both in right ascension and declination, as the clock error and the equator point of the circle were always determined by observations of a few stars selected from the *Berliner Jahrbuch.* These stars, which were chosen as being conveniently situated in regard to the time of their culmination, and because their zenith distances did not greatly differ from that of Dr. Gill's stars, are contained in the following list:—

List of Standard Stars.

No.	No. in Fund. Cat.	Name.	Mean R.A. 1888·0.	Mean Decl. 1888·0.
			h m s	° ′ ″
1	15	ε Piscium	0 57 7·815	+ 7 17 13·22
2	22	η Piscium	1 25 29·397	+14 46 5·08
3	25	ο Piscium	1 39 28·734	+ 8 35 37·31
4	27	α Triang.	1 46 41·867	+29 1 58·17
5	30	β Arietis	1 48 27·172	+20 15 36·63
6	42	μ Ceti	2 38 53·207	+ 9 38 26·70
7	44	41 Arietis	2 43 23·480	+26 47 53·75
8	47	α Ceti	2 56 25·448	+ 3 38 59·23
9	359	δ Arietis	3 5 13·470	+19 18 8·83

The azimuth error of the instrument was on every occasion determined by observations of *Polaris* at upper culmination, in combination with the clock stars observed. The other errors of the instrument were determined, and the observations reduced, in the manner described in the Fourth and the Sixth Parts of the *Dunsink Observations and Researches*. In addition to the observations of standard stars in zenith distance, readings of the nadir point of the circle were also taken, two before and two after, each series of observations. The equator point, as determined from these nadir readings, is given in the eighth column of the *Table of Instrumental Corrections*. In obtaining this quantity the latitude of the meridian circle is taken as being 53° 23′ 13″·1, as determined from a series of observations of *Polaris* above and below the pole, made during the winter of 1887–88, an account of which will shortly be published in the *Scientific Transactions of the Royal Dublin Society*. The seventh column of the same table contains this quantity as derived from observations of standard stars, and this alone has been used in the reductions.

The numbers in the ninth column refer to the list of standard stars given above, and show what stars were observed on each night.

The symbol (α) or (δ) following any number implies that the star corresponding to this number was observed only in right ascension or declination as the case may be.

Table of Instrumental Corrections.

The values of the various quantities in this table are computed for the epoch 2ʰ·0 Sidereal Time.

Date.	Clamp.	Incl.	Azim.	Collim.	$\Delta t + b \sec \phi$.	Equator Point (S.)	(N.)	Standard Stars.
1888.		s	s	s	s	° ′ ″	″	
Sept. 5	W	+0·202	−0·206	−0·048	−197·28	171 36 37·59	37·56	1, 2, 6, 7
7		+0·200	−0·246	−0·046	−200·93	38·09	38·10	1, 2, 6, 8
12		+0·163	−0·291	−0·052	− 29·28	36·81	36·85	1 (δ), 2, 4, 7, 8 (α)
16		+0·166	−0·143	−0·016	− 35·76	36·49	36·52	1, 2, 7, 8
26		+0·180	−0·082	+0·003	− 53·09	36·54	36·71†	1, 2
Oct. 1		+0·202	−0·156	[0·000]	− 62·19	39·22	††	2, 4, 7, 8
3		+0·138	−0·100	+0·003	− 65·22	38·83	††	1 (α), 2, 3, 6
4		+0·139	−0·055	+0·019	− 66·70	40·16	40·59	1 (α), 2 (δ), 3, 7, 8
13	E	+0·086	−0·098	−0·144	− 74·92	171 37 26·73	26·62	1, 2, 6, 7
14		+0·061	−0·153	−0·180	− 75·68	26·75	26·35	1, 2, 6, 7
20		+0·067	−0·069	−0·136	− 80·47	24·94	24·97	1, 2, 5, 6, 7
22		+0·089	−0·014	−0·125	− 82·17	26·10	25·98	1, 2, 6, 7
30		+0·182	−0·198	−0·188	− 92·09	27·71	27·47	1, 2, 6, 7
Nov. 16		+0·092	−0·230	−0·166	−118·90	25·86	25·97†	1, 2
20		+0·123	−0·266	−0·169	−124·42	27·24	27·42	2, 3, 6, 7
25		+0·112	−0·132	−0·018*	−130·17	25·34	25·03	1, 2, 6, 7
27		+0·136	−0·094	+0·008	133·30	26·67	25·97	1, 2, 6, 7

Date.	Clamp.	Incl.	Azim.	Collim.	$\Delta t + b \sec \phi$.	Equator Point (S.)	(N.)	Standard Stars.
1888.		s	s	s	s	° ′ ″	″	
Nov. 30		+0·091	[−0·162]	−0·024	− 17·58	171 37 26·11	††	5, 6, 7
Dec. 3		+0·049	−0·231	−0·051	− 21·04	23·51	22·78	2, 5, 6 (8), 7
8		+0·114	−0·186	−0·019	− 26·43	26·17	25·68	1, 2, 6, 7
9		+0·109	−0·181	−0·017	− 27·54	26·32	26·15	1, 2, 6, 7
11	W	+0·040	[−0·211]**	+0·077	− 29·90	171 36 38·16	38·04†	6, 7, 8, 9
16		+0·040	−0·161	+0·028	− 35·21	38·77	38·55	2, 3, 6, 9
20		−0·016	−0·146	+0·083	− 40·07	36·71	37·26	2, 3, 6, 7
24		+0·015	−0·121	+0·064	− 45·33	37·38	37·20	2, 3, 6, 7
26		+0·016	−0·286	+0·004	− 47·83	38·49	38·23	2, 3, 6, 7
27		−0·007	−0·210	+0·025	− 49·26	38·25	37·62	2, 3, 6, 7
28	E	+0·010	−0·276	−0·002	− 50·58	171 37 24·39	23·52	2, 3, 6, 7
29		+0·038	−0·220	+0·026	− 51·86	24·27	23·79	2, 3, 6, 7
30		+0·023	−0·191	+0·011	− 53·03	25·45	24·95	2, 3, 6, 7
1889. Jan. 3		−0·052	−0·195	+0·033	− 57·17	24·81	23·76	2, 3, 6, 7
5	W	−0·105	−0·270	+0·026	− 59·07	171 36 37·76	37·08	2, 3, 6, 7
10	W	−0·083	−0·260	+0·044	− 63·96	37·68	36·45	2, 3, 6, 9

* Spider lines cleaned on November 24.
** Determined on December 10.

† Only two determinations of nadir.
†† Nadir not observed.

Probable Error of the Resulting Places.

I have computed the probable error of a single observation of right ascension from the whole series of results, and I find that for a star of declination +20° 30′ (the mean declination of Dr. Gill's list) it is

$$\pm 0^{s}\cdot 032,$$

which corresponds to a probable error of $\pm 0^{s}\cdot 030$ at the equator.

In declination the probable error of a single observation as computed from the whole series is

$$\pm 0''\cdot 405.$$

Separate Results.

No.	D.M.	Date.	Clamp.	R.A. 1880·0.	Decl. 1880·0.	Remarks.
		1888.		h m s	° ′ ″	
1	+17°, 307	Sept. 5	W	1 57 34·09	+17 42 52·7	
		7	W	33·99	53·8	
		Oct. 13	E	33·91	51·9	
		14	E	33·97	52·1	
		Dec. 24	W	33·95	52·3	
		27	W	33·98	52·3	
		29	E	33·95	51·7	
				1 57 33·960	+17 42 52·40	
2	+19°, 324	Sept. 12	W	2 0 4·00	+20 3 26·8	
		16	W	3·91	25·8	
		Oct. 20	E	3·88	25·9	
		22	E	3·97	26·0	
		Dec. 26	W	3·92	25·9	
		28	E	3·91	25·2	
				2 0 3·932	+20 3 25·93	
3	+17°, 315	Sept. 26	W	2 1 36·99	+17 29 43·8	See note (*a*).
		Oct. 1	W	37·06	43·8	Very unsteady.
		30	E	37·04	44·1	
		Nov. 16	E	37·03	[45·2]	See note (*b*).
		Dec. 30	E	36·99	43·8	
		1889. Jan. 10	W	37·09	43·0	Through clouds
				2 1 37·033	+17 29 43·70	

No.	D.M.	Date.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
4	+16°, 247	1888. Oct. 3	W	2 3 14·05	+16 41 56·9	See note (*c*).
		4	W	13·78	54·7	
		13	E	13·93	55·1	
		14	E	13·81	54·3	Rather unsteady.
				2 3 13·892	+16 41 55·25	
5	+19°, 329	Sept. 5	W	2 3 29·90	+19 49 2·4	
		7	W	29·95	4·2	
		Dec. 16	W	29·85	2·4	
		29	E	29·87	1·4	
				2 3 29·892	+19 49 2·60	
6	+18°, 277	Nov. 20	E	2 4 25·07	+18 58 —	
		Dec. 20	W	25·07	18·1	Dark field.
		24	W	25·03	18·0	Dark field.
		28	E	25·08	18·1	
		1889. Jan. 3	E	25·05	18·0	
				2 4 25·060	+18 58 18·05	
7	+20°, 341	1888. Oct. 22	E	2 5 6·09	+20 50 57·2	
		Dec. 26	W	6·08	57·6	
		27	W	6·04	56·9	
		30	E	5·95	56·0	
				2 5 6·040	+20 50 56·92	
8	+21°, 298	Nov. 27	E	2 6 2·89	+21 27 25·7	
		30	E	2·94	24·9	
		Dec. 11	W	2·89	26·4	
		1889. Jan. 5	W	2·88	26·7	
				2 6 2·900	+21 27 25·92	
9	+20°, 348	1888. Sept. 16	W	2 6 31·90	+20 41 5·0	
		26	W	—	5·5	
		Oct. 20	E	31·78	3·7	
		30	E	31·84	3·0	
		1889. Jan. 10	W	31·90	3·4	
				2 6 31·855	+20 41 4·12	

No.	D.M.	Date.	Clamp.	R.A. 1880·0.	Decl. 1880·0.	Remarks.
		1888.		h m s	° ′ ″	
10	+18°, 283	Sept. 12	W	2 7 38·96	+19 5 23·2	
		Oct. 1	W	38·91	23·0	
		Nov. 25	E	38·89	22·3	
		Dec. 9	E	38·78	21·9	
				2 7 38·885	+19 5 22·60	
11	+21°, 304	Sept. 5	W	2 8 39·57	+22 6 26·0	
		7	W	39·71	25·8	
		Dec. 3	E	39·61	25·6	
		8	E	39·67	26·1	Set hurriedly.
		28	E	39·64	26·0	A ✱ 8·5 mag. s.p.
		29	E	39·58	26·1	
				2 8 39·630	+22 6 25·93	
12	+21°, 317	Oct. 3	W	2 11 26·21	+22 8 33·2	See note (*d*).
		4	W	26·10	35·1	
		13	E	26·14	36·1	
		14	E	26·12	34·7	
				2 11 26·133	+22 8 34·77	
13	+19°, 340	Nov. 20	E	2 11 53·63	+19 22 57·2	Through clouds.
		30	E	53·72	56·4	
		Dec. 11	W	53·67	57·1	
		16	W	53·62	57·0	
		30	E	53·63	56·5	
				2 11 53·654	+19 22 56·84	
14	+21°, 321	Oct. 22	E	2 12 16·91	+21 22 49·4	See note (*e*).
		30	E	16·90	49·7	
		Dec. 20	W	16·77	49·4	Dark field.
		24	W	16·88	49·8	
				2 12 16·865	+21 22 49·57	
15	+22°, 329	Sept. 16	W	2 12 38·52	+22 39 3·5	
		Oct. 1	W	38·42	4·4	
		20	E	38·46	2·6	
		Dec. 9	E	38·37	2·0	
		1889. Jan. 10	W	38·50	2·3	
				2 12 38·452	+22 39 2·96	

No.	D.M.	Date.	Clamp.	R.A. 1880·0.	Decl. 1880·0.	Remarks.
		1888.		h m s	° ′ ″	
16	+19°, 346	Sept. 7	W	2 14 17·86	+19 36 36·9	See note (*f*).
		12	W	17·97	36·2	
		Dec. 3	E	18·01	36·0	Dark field.
		Dec. 26	W	17·95	34·8	See note (*g*).
		1889. Jan. 3	E	17·95	35·5	Dark field.
				2 14 17·948	+19 36 35·88	
		1888.				
17	+22°, 331	Nov. 27	E	2 14 53·79	+22 54 47·6	
		Dec. 8	E	53·96	47·6	
		11	W	53·93	47·2	
		16	W	53·93	47·7	
				2 14 53·902	+22 54 47·52	
18	+20°, 388	Sept. 5	W	2 17 29·95	+20 54 16·6	
		16	W	[30·18]	17·6	See note (*h*).
		Oct. 13	E	29·99	17·5	
		14	E	29·93	17·7	
		Dec. 24	W	29·90	16·9	Dark field.
				2 17 29·943	+20 54 17·26	
19	+24°, 347	Sept. 26	W	2 19 27·20	+24 39 10·7	See note (*i*).
		Oct. 1	W	27·35	12·8	See note (*j*).
		20	E	27·36	10·9	
		Nov. 20	E	27·37	10·4	
				2 19 27·320	+24 39 11·20	
20	+22°, 347	Sept. 7	W	2 20 38·07	+22 22 28·1	
		12	W	37·93	26·9	
		Nov. 25	E	37·93	27·2	
		Dec. 3	E	38·09	27·4	See note (*k*).
		1889. Jan. 10	W	38·01	27·3	See note (*l*).
				2 20 38·006	+22 22 27·38	
		1888.				
21	+23°, 326	Nov. 27	E	2 21 53·25	+24 7 45·1	See note (*m*).
		Dec. 9	E	53·24	45·5	
		11	W	53·27	43·0	
		16	W	53·28	44·6	
				2 21 53·260	+24 7 44·55	

No.	D.M.	Date.	Clamp.	R.A. 1880·0.	Decl. 1880·0.	Remarks.
		1888.		h m s	° ′ ″	
22	+22°, 345	Oct. 3	W	2 22 50·60	+22 58 6·4	Dark field.
		4	W	50·59	6·9	Good.
		13	E	50·55	6·8	Dark field.
		14	E	50·49	6·5	
		1889. Jan. 5	W	50·60	5·8	
				2 22 50·566	+22 58 6·48	
		1888.				
23	+20°, 404	Sept. 16	W	2 22 57·67	+21 5 39·1	
		Nov. 30	E	57·73	38·2	
		Dec. 26	W	57·67	37·7	
		27	W	57·64	37·3	
		28	E	57·72	38·4	See note (*n*).
				2 22 57·686	+21 5 38·14	
24	+24°, 358	Sept. 5	W	2 24 5·78	+24 44 17·4	
		Oct. 30	E	5·78	18·3	
		Dec. 20	W	5·75	17·3	Dark field.
		24	W	5·76	17·1	
		29	E	5·80	17·6	
		30	E	5·78	17·9	
				2 24 5·775	+24 44 17·60	
25	+21°, 349	Sept. 12	W	2 26 1·67	+21 50 17·5	
		Oct. 1	W	1·65	17·4	
		Nov. 20	E	1·66	17·3	Through clouds.
		25	E	1·71	17·3	
				2 26 1·672	+21 50 17·37	
26	+24°, 369	Sept. 16	W	2 28 11·90	+24 24 4·1	
		26	W	11·76	2·5	See note (*o*).
		Dec. 3	E	11·92	3·4	See note (*p*).
		9	E	11·78	4·0	
				2 28 11·840	+24 24 3·50	
27	+22°, 368	Oct. 4	W	2 28 16·64	+22 28 35·1	
		Nov. 27	E	16·59	35·2	
		Dec. 8	E	16·65	35·4	
		11	W	16·59	34·2	
				2 28 16·617	+22 28 34·97	

No.	D.M.	Date.	Clamp.	R.A. 1880·0.	Decl. 1880·0.	Remarks.
		1888.		h m s	° ′ ″	
28	+22°, 372	Sept. 5	W	2 30 18·60	+22 33 49·4	
		Oct. 30	E	18·71	50·4	
		Nov. 30	E	18·70	49·5	
		Dec. 24	W	18·68	49·1	
		29	E	18·64	48·8	
		1889. Jan. 5	W	18·70	49·3	
				2 30 18·672	+22 33 49·42	
		1888.				
29	+24°, 376	Oct. 20	E	2 30 32·90	+24 9 33·3	D.M. +24°, 375 p., 3″ ± n.
		22	E	33·01	33·6	Oct. 20 Δα = 2^s·85
		Dec. 16	W	32·95	32·9	„ 22 Δα = 3^s·07
		20	W	32·98	33·1	Dec. 30 Δα = 2^s·78
		3	E	32·97	33·3	Δα = 2^s·90
				2 30 32·962	+24 9 33·24	
30	+22°, 375	Nov. 20	E	2 31 25·30	+22 38 34·0	
		25	E	25·34	34·0	
		Dec. 26	W	25·32	33·7	Rather unsteady.
		27	W	25·31	33·0	
		28	E	25·32	33·9	Dark field.
				2 31 25·318	+22 38 33·72	

Notes.

(*a*) Through thin clouds.

(*b*) Microscopes V. and VI. were read immediately. Then the telescope was set for *Iris*, after which the telescope was re-set by the first two readings, and those of VII. and VIII. taken.

(*c*) Dark field. Faint through clouds.

(*d*) Dark field. Observed across only five wires. Half weight in R.A.

(*e*) Through clouds. Appears brighter than 8^m.

(*f*) A 9^m star f. $6^s·5$, $2'$ ± s. (*g*) Rather faint for bright field.

(*h*) R.A. very bad. Appears less than $8^m·5$. Reject.

(*i*) Through clouds. Faint. Dark field.

(*j*) Through clouds, drifting swiftly by. (*k*) Very faint through clouds.

(*l*) Faint through clouds. Decl. appeared good as seen once or twice through clear breaks.

(*m*) A star, R.A. 2^h 19^m $25^s·60$, Decl. + 24° 10′ 5″·3, observed on December 8, 1888, by mistake for this.

(*n*) Faint through clouds. Dark field.

(*o*) Through clouds. Dark field.

(*p*) Very faint through clouds. Dark field.

Observations of the Planet Iris.

[The places given in this list are not corrected for annual aberration or parallax.]

Date.		App. R.A.	App. Decl.	Remarks.
1888.		h m s.	° ′ ″	
Sept.	7	2 29 47·89	+23 27 50·9	Ill-defined.
	12	32 34·65	+23 49 55·2	Appears slightly reddish. A ✱ 8ᵐ (D.M. + 23°, 349) *f.* 13ˢ·5, 20″ ± *n.*
	16	34 12·35	+24 3 53·4	
	26	35 47·89	+24 22 46·2	Through clouds. Only five wires.
Oct.	1	35 13·05	+24 22 41·9	Ill-defined.
	3	34 43·99		Only two wires. Appeared for only a few secs. through clouds.
	4	34 26·21	+24 19 18·5	
	13	30 18·64	+23 53 30·9	Very well seen. Blue rather than red.
	14	29 42·50	+23 49 11·3	
	20	25 37·76	+23 17 33·7	
	22	24 7·72	+23 4 54·5	Definition good.
	30	17 45·70	+22 5 20·8	
Nov.	16	5 52·90		Only three wires. Scarcely visible.
	20	4 4·09	+18 58 49·8	D.M. + 18°, 277, *f.* 24ˢ·11, 17″ ± *s.*
	25	2 32·47	+18 18 3·6	
	27	2 10·34	+18 2 53·0	
	30	1 53·65	+17 51 31·3	
Dec.	8	2 47·36	+16 54 8·1	
	9	3 3·94	+16 49 14·0	D.M. + 16°, 247, *f.* 11ˢ ±, 7′ ± *s.* in same field.
	11	3 44·19	+16 40 10·1	Only two microscopes (V. and VI.) read at once. I afterwards reset by means of these, and read VII. and VIII.
	26	13 5·74	+16 1 59·7	Only five wires. Only one microscope (V.) read until after the transit of 41 *Arietis.*
	27	13 58·25	+16 1 12·8	
	28	14 52·66	+16 0 38·0	A 9ᵐ·5 ✱ *p.* 2ˢ·5, 1′ ± *n.* not in D.M.
	29	15 48·54	+16 0 14·3	
	30	16 46·29	+16 0 2·5	Appeared about 8ᵐ·5 through a slight haze.
1889.				
Jan.	10	2 29 5·59	+16 9 45·1	Another star of same mag. (D.M. + 15°, 354) 26ˢ·75 *f.* from 2′ to 3′ south.

On December 3 the star D.M. + 17°, 315 was observed by mistake for *Iris.* The resulting place is R.A. $2^h\ 1^m\ 37^s{\cdot}03$, Decl. $+17°\ 29'\ 43''{\cdot}4$.

Mean Places of Comparison Stars for Heliometer Observations of Iris.

No.	Mag.	Mean R.A. 1888·0.	Ann. Prec.	Sec. Var.	No. of Obs.	Mean. Decl. 1888·0.	Ann. Prec.	Sec. Var.	References.
		h m s	s	s		° ′ ″	″	″	
1	7·0	1 57 33·960	+3·28207	+0·01681	7	+17 42 52·40	+17·4720	−0·2425	Arm. 454, P. 243, T. 673, W. 1331, 7 yr. 136, 9 yr. 192.
2	7·7	2 0 3·932	·31666	·01837	6	20 3 25·93	17·3637	·2494	W. 1397.
3	7·3	2 1 37·033	·28576	·01673	6, 5	17 29 43·70	17·2953	·2499	Gl. 465, P. 257, W. 1436.
4	6·8	2 3 13·892	·27789	·01626	4	16 41 55·25	17·2234	·2521	W. 1482.
5	7·5	2 3 29·892	·31972	·01824	4	19 49 2·60	17·2114	·2558	W. 1.
6	6·0	2 4 25·060	·30991	·01770	5, 4	18 58 18·05	17·1699	·2567	Arm. 473, B. 296, B.A.C. 669, P. 267, T. 702, W. 19, Y. 977, 7 yr. 139, 9 yr. 198.
7	7·5	2 5 6·040	·33681	·01894	4	20 50 56·92	17·1391	·2600	Gl. 479, P. 1, R C_2 265, W. 43.
8	8·5	2 6 2·900	·34713	·01937	4	21 27 25·92	17·0959	·2625	W. 75.
9	5·5	2 6 31·855	·33722	·01884	4, 5	20 41 4·12	17·0737	·2625	Arm. 482, B. 303, P. 11, R C_2 272, T. 718, W. 87, Y. 996, 12 yr. 193, 7 yr. 141.
10	7·2	2 7 38·885	·31706	·01780	4	19 5 22·60	17·0223	·2629	Arm. 486, T. 728, W. 130.
11	7·8	2 8 39·630	·36159	·01982	6	22 6 25·93	16·9753	·2684	
12	8·3	2 11 26·133	·36766	·01986	4	22 8 34·77	16·8449	·2735	W. 233.
13	6·0	2 11 53·654	·32847	·01801	5	19 22 56·84	16·8230	·2713	Arm. 502, $Arm._2$ 296, B. 320, P. 49, Pond (1830) 72, R C_2 282, Y. 1029, 9 yr. 210, 12 yr. 204, 7 yr. 148.
14	8·0	2 12 16·865	·35809	·01934	4	21 22 49·57	16·8046	·2744	W. 241.

No.	Mag.	Mean R.A. 1888.0.	Ann. Prec.	Sec. Var.	No. of Obs.	Mean Decl. 1888.0.	Ann. Prec.	Sec. Var.	References.
		h m s	s	s		° ′ ″	″	″	
15	6.0	2 12 38.452	+3.37764	+0.02022	5	+22 39 2.96	+16.7874	−0.2765	Arm. 297.
16	8.5	2 14 17.948	.33590	.01816	5	19 36 35.88	16.7077	.2762	
17	7.8	2 14 53.902	.38623	.02040	4	22 54 47.52	16.6786	.2813	
18	8.5	2 17 29.943	.36079	.01901	4, 5	20 54 17.26	16.5512	.2837	W. 368.
19	7.3	2 19 27.320	.42322	.02166	4	24 39 11.20	16.4539	.2924	
20	7.8	2 20 38.006	.38938	.02000	5	22 22 27.38	16.3947	.2916	W. 444, Y. 1081.
21	8.6	2 21 53.260	.42000	.02124	4	24 7 44.55	16.3313	.2965	
22	6.0	2 22 50.566	.40321	.02041	5	22 58 6.48	16.2826	.2966	Arm.$_2$ 319, R. 631, R.$_2$ 1267.
23	7.5	2 22 57.686	.37371	.01911	5	21 5 38.14	16.2766	.2945	W. 503.
24	6.2	2 24 5.775	.43476	.02167	6	24 44 17.60	16.2184	.3016	Arm. 544, W. 525, Y. 1101.
25	8.0	2 26 1.672	.39122	.01960	4	21 50 17.37	16.1184	.3011	W. 587, Y. 1122.
26	8.2	2 28 11.840	.43788	.02136	4	24 24 3.50	16.0048	.3090	W. 635.
27	8.1	2 28 16.617	.40589	.02001	4	22 28 34.97	16.0006	.3063	W. 637.
28	7.6	2 30 18.672	.41125	.02004	6	22 33 49.42	15.8926	.3102	W. 688.
29	7.0	2 30 32.962	.43869	.02117	5	24 9 33.24	15.8799	.3130	Arm. 565, Arm.$_2$ 338, B. 361, P. 128, R C$_2$ 314, T. 867, W. 693, Y. 1150, 12 yr. 224.
30	8.3	2 31 25.318	+3.41471	+0.02007	5	+22 38 33.72	+15.8331	−0.3123	W. 710.

The abbreviations in the last column are the same as those used in the second Armagh Catalogue, which is here denoted by Arm.$_2$.

Dunsink: 1889, *February* 26.

Observations of the Variable Star S (10) Sagittæ. By J. E. Gore.

The following are my observations of this short period variable during the year 1888. They form a continuation of the observations given in *Monthly Notices* for March 1888.

The comparison stars are as before.

	Mag.
11 Sagittæ	5·8
DM. + 16°, 4086	7·0

Date.	Dublin M.T. h m	Mag.	Date.	Dublin M.T. h m	Mag.
1888, Jan. 2	6 22	6·25	1888, Oct. 22	10 10	6·5
5	5 45	5·65	Nov. 6	7 55	6·16
8	6 10	5·7	9	7 37	6·16
Oct. 5	10 15	6·25	13	7 30	5·85
10	10 40	5·7	14	6 45	6·16
12	10 15	6·0	25	6 48	6·28
13	7 35	6·16	27	8 55	5·7
13	10 42	6·25	30	6 44	5·9
14	6 58	6·28	Dec. 7	7 34	5·8
16	10 15	5·7	8	8 2	5·8
20	9 25	6·25	9	6 36	5·9
22	7 52	6·4	26	6 40	5·9

Note on a Red Star. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Whilst searching for Faye's Comet on the night of 1888, November 27, which could not be seen with the 10-inch Barclay equatorial, a star was noticed by Mr. Bellamy as "a vividly red coloured star."

On February 9, 1889, Mr. Robinson looked for the above star, and made the following observations: "This star was easily picked up from its colour contrasting with all the other stars in the vicinity. It is undoubtedly red. A white star, slightly fainter, precedes 4′ N.; also a bright white star follows 6′ S. The star turns out to be Lalande 16320, and the following are the positions of the star and those compared with it on 1889, February 9.

	Approx. R.A. 1889·0. h m s	Approx. N.P.D. ° ′ ″	Colour.	Observed Magnitude.
Lamont 22	8 13 31	86 49 19	White	8·75
Lalande 16320	8 14 18	86 53 13	Red	8·5
Lalande 16341	8 14 54	86 59 4	White	7·0

Radcliffe Observatory, Oxford:
1889, *March* 7.

Observations of Comet Barnard (1888, *September* 2) *and Comet Barnard* (1888, *October* 30), *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following observations were made with the Barclay equatorial, using the ring-micrometer, with power 100.

Comet Barnard (1888, *September* 2).

Date.	G.M.T.	Local Sidereal Time.	Observer.	☄−✱ (Corrected for Refraction only.) R.A.	☄−✱ N.P.D.	No. of Comparisons.	Apparent R.A. of Comet.	Parallax in R.A./p	Log ($p\times\Delta$).	Apparent N.P.D. of Comet.	Parallax in N.P.D./q	Log ($q\times\Delta$).	Reference to Comparison Star.
1888.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Nov. 26	8 56 30	1 16 18	F. B.	−0 32·68	+1 35·0	6	2 49 14·51	−0·13	9·1598	95 11 22·4	−6·66	0·8653	(a)
26	8 56 39	1 16 27	F. B.	−3 10·50	+1 4·6	7	2 49 13·94	−0·13	9·1598	95 11 15·7	−6·66	0·8653	(b)
26	9 7 40	1 27 30	F. B.	−0 35·87	+1 39·4	8	2 49 11·32	−0·12	9·1067	95 11 26·8	−6·67	0·8658	(a)
27	9 52 5	2 15 59	W.	−0 36·05	+6 12·2	12	2 42 12·64	−0·04	8·6210	95 26 54·8	−6·67	0·8686	(c)
27	10 17 59	2 41 57	W.	−0 42·78	+6 23·7	3	2 42 5·91	0·00	...	95 27 6·3	−6·68	0·8688	(c)
27	10 17 59	2 41 57	W.	−2 43·50	+0 13·8	3	2 42 5·82	0·00	...	95 27 8·0	−6·68	0·8688	(d)
27	13 24 3	5 48 32	F. B.	+0 46·16	...	7	2 41 12·88	+0·24	9·4274	...	...	...	(e)
27	13 24 3	5 48 32	F. B.	−1 37·17	+5 45·7	7	2 41 12·71	+0·24	9·4274	95 28 48·7	−6·53	0·8592	(f)
Dec. 22	9 13 2	3 15 23	R.	−0 28·34	−6 14·7	7	0 41 37·67	+0·15	9·3599	97 39	−4·86	0·8701	(g)
1889. Feb. 9	6 50 48	4 5 57	R.	+0 47·79	...	5	23 42 28·69	+0·13	9·5259	...	...	...	(h)
9	6 53 0	4 8 9	R.	...	−2 17·4	4	...	...	...	94 29 3·9	−2·75	0·8485	(h)

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent R.A.	Mean N.P.D. 1888·0.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	2 49 44·27	+2·92	95 9 55·8	− 8·4	W. B. II. 838.
(*b*)	2 52 21·52	+2·92	95 10 19·3	− 8·3	W. B. II. 887.
(*c*)	2 42 45·80	+2·89	95 20 51·1	− 8·5	Pola Meridian Obs. *Ast. Nach.* No. 2819.
(*d*)	2 44 46·42	+2·90	95 27 2·6	− 8·4	Mean of Karlsruhe (1885) and Radcliffe (1883).
(*e*)	2 40 23·83	+2·89	95 25 43·7	− 8·6	Mean of Karlsruhe (1885) and Radcliffe (1886).
(*f*)	2 42 46·98	+2·90	95 23 11·5	− 8·5	Mean of W. B. II. 708 and Schjellerup 785.
(*g*)	0 42 3·82	+2·19	97 46	− 9·3	Schön. Z. −7°, No. 124.
	Mean R.A. 1889·0.		Mean N.P.D. 1889·0.		
(*h*)	23 41 41·54	−1·64	94 31 10·4	+10·9	Mean of Schön. Z.−4°, 5955 and 1 equatorial comparison with W. B. XXIII. 1041.

Observers' Remarks.

1888, Nov. 26.—Nucleus 10–9 mag. Nov. 27.—Distinct planetary nucleus about 10 mag.
Nov. 27, 13h.—Nucleus fainter than on Nov. 26, being now about 10½ mag. Dec. 22.—Nucleus mag. 10.
1889, Feb. 9.—Comet very faint, only just discernible. Like a small circular nebula with central condensation. Comet low.

In the computations of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, have been taken from the *Astronomische Nachrichten*, Nos. 2867 and 2868.

Observations of Comet Barnard (1888, *September* 2) **with the Transit-circle.**

Date.	G.M.T. of Transit.	Observer.	Apparent R.A. of Comet.	Apparent N.P.D. of Comet.	Parallax N.P.D. / q	Log $(q \times \Delta)$.	Observer's Remarks.
1888.	h m s		h m s	° ′ ″	″		
Nov. 16	12 16 39	F. B.	3 57 34·18	92 9 20·8	−6·43	0·8515	Faint; difficult observation.
20	11 33 35	F. B.	3 30 9·59	93 28 39·1	−6·62	0·8587	Nucleus 10–11. Difficult but satisfactory observation.
22	11 11 51	F. B.	3 16 15·32	94 5 39·8	−6·71	0·8620	Thin clouds passing. Difficult.
27	10 18 8	F. B.	2 42 5·62	95 27 8·2	−6·67	0·8688	Not a satisfactory observation; comet very faint.

In the computation of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, have been taken from the *Astronomische Nachrichten*, Nos. 2861 and 2867.

Comet Barnard (1888, *October* 30).

The following observations were made with the Barclay equatorial, using the ring-micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	☄ − ✱ (Corrected for Refraction only.) R.A.	☄ − ✱ N.P.D.	No. of Comparisons.	Apparent R.A. of Comet.	Parallax in R.A. / p	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. / q	Log $(q \times \Delta)$.	Reference to Comparison Star.
1888.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Nov. 27	15 11 14	7 36 0	F. B.	−1 11·76	...	8	10 16 58·38	−0·15	9·3792	99 51	−4·70	0·8761	(*a*)
27	15 11 14	7 36 0	F. B.	−1 43·92	+1 0·7	8	10 16 57·42	−0·15	9·3792	99 51	−4·70	0·8761	(*b*)
1889. Jan. 29	11 28 6	8 0 39	F. B.	+1 46·08	+7 3·7	9	10 5 49·91	−0·14	9·3013	71 22 38·2	−3·52	0·7029	(*c*)
29	12 10 52	8 43 32	F. B.	−1 17·69	+4 55·6	9	10 5 47·79	−0·09	9·1312	71 21 44·9	−3·42	0·6905	(*d*)
Feb. 1	12 39 23	9 23 57	W.	+0 53·49	+4 39·1	9	10 2 27·93	−0·05	8·8127	69 44 3·6	−3·17	0·6634	(*e*)

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent R.A.	Mean N.P.D. 1888·0.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′	″	
(*a*)	10 18 8·31	+1·83	99 52	+5·4	Schön. Z. −9°, No. 3059.
(*b*)	10 18 39·51	+1·83	99 49	+5·4	Schön. Z. −9°, No. 3063.
	Mean R.A. 1889·0.		Mean N.P.D. 1889·0.		
	h m s		° ′ ″		
(*c*)	10 4 3·33	+0·50	71 15 29·2	+5·2	Bonn Meridian Observations, vol. vi.
(*d*)	10 7 4·99	+0·49	71 16 44·1	+5·2	Bonn Meridian Observations, vol. vi.
(*e*)	10 1 33·88	+0·56	69 39 19·2	+5·4	Radcliffe Transit-circle Observation, 1889, Feb. 4.

Observers' Remarks.

1888, Nov. 27.—A faint nebulous, almost circular, patch, about 1¼′ in diameter. Nucleus only seen at times, and is of the 11½ mag. Observations difficult; moonlight and haze.

1889, Jan. 29.—Nucleus stellar but slightly elongated, mag. 11½ or 12. Surrounded by a moderately bright nebulosity about 4′ in diameter. No tail.

Feb. 1.—The comet is a hazy patch of about 1′ diameter with a stellar nucleus, mag. 13.

In the computations of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, have been taken from the *Astronomische Nachrichten*, Nos. 2867 and 2871.

Observers: W.—Mr. W. Wickham; R.—Mr. W. H. Robinson; F. B.—Mr. F. A. Bellamy.

N.B.—The N.P.D. of the Comparison Star (*a*), *Monthly Notices*, vol. xlix. No. 2, page 84, is 7″·5 too small, and the N.P.D. of Comet Barnard (1888, Sept. 2) observed on Oct. 5 requires, therefore, to be increased by 7″·5.

Radcliffe Observatory, Oxford:
1889, *March* 7.

Discovery of Comet Brooks, a 1889. By William R. Brooks.

While sweeping the eastern heavens in the neighbourhood of the Sun, on the morning of January 15, 1889, at $6^h\ 5^m$ L.M.T., I discovered a new comet in approximately R.A. $18^h\ 04^m$; declination south 21° 20′. I had only time to take the circle readings for position—the instrument used being the new $10\frac{1}{8}$ inch equatorial of this observatory, with a large achromatic positive eyepiece giving a power of 40 diameters, and a field of 1° 20′. The nearly full Moon was just setting, and the dawn approaching, so I had but a short time in which to do my work; but fortunately the comet was in a well-marked field of telescopic stars, and so I was enabled to detect motion in a few minutes, which was rapid in a westerly course.

In the annexed diagram I show the stars used to detect motion, by alineation, my usual custom. The comet was nearly round, with slight central condensation. It was "faintish," yet brighter than well-known nebulæ in that region which were not seen. I was *sure* of its cometary nature, as I am now, and also of *motion*, which was unmistakable. Immediate telegraphic announcement was made of the discovery.

Clouds prevented another observation of the comet until the morning of the 20th, when careful sweeps were made in the direction of motion from the place of discovery, but the search was unsuccessful, owing to the bright moonlight—the Moon being only three days past the full. No other opportunity has since offered at this observatory to re-observe the comet. It must now be a long distance west of its position at the time of discovery and probably fainter, for I must have caught the object just as it was sweeping upwards from the Sun. Yet it is hoped that the comet may not be beyond telescopic reach when the present Moon is out of the way.

Smith Observatory, Geneva, N.Y., U.S.A.:
1889, *January* 25.

Observations of Comet f 1888 (*Barnard*), *made at Stonyhurst College Observatory.* By W. J. Crofton, S.J., B.A.

(*Communicated by the Rev. S. J. Perry.*)

1889.	G.M.T.	✱−☄ R.A.	✱−☄ N.P.D.	Apparent place of ☄ R.A.	Apparent place of ☄ N.P.D.	No. of Comps.	Comp. Star.
	h m s	s	′ ″	h m s	° ′ ″		
Jan. 22	11 3 57	−31·52	+12 33·4	10 13 0·75	75 18 13·2	3	(*a*)
Feb. 4	9 55 46	−19·2	− 4 5·5	9 59 11·4	68 12 48	4	(*b*)

Comparison Stars.

Comp. Star.	Mean R.A. 1889·0.	Reduction to date	Mean N.P.D. 1889·0.	Reduction to date.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	10 12 28·89	+0·34	75 30 41·8	+4·8	W.B.X. 170, Berl. Acad. Zon. X. Lal. 19990.
(*b*)	9 58 51·6	+0·61	68 8 37	+5·5	D.M. +22°, 2172.

Observers: W. J. Crofton and W. Carlisle.

The observations were taken over two bars at right angles and inclined at 45° to the declination circle. The corrections for refraction and parallax have been applied.

On January 22 the comet was faint and diffuse, without any clearly marked nucleus. The observation of February 4 is somewhat uncertain.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the year 1888. By John Tebbutt.

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Mar. 27	I.	Ecl. D.	Began to fade	4½-inch	90	23 36 40	23 37 21
27	I.	"	Last seen	"	"	23 37 58	
April 2	I.	"	Began to fade	8-inch	95	7 2 16	7 2 30
2	I.	"	Last seen	"	"	7 3 26	
9	II.	Tr. Egr.	Ext. contact	"	130	0 47 7	0 46
14	III.	Ecl. D.	Began to fade	"	"	23 30 19	23 33 22
14	III.	"	Last seen	"	"	23 39 18	
15	III.	Ecl. R.	First seen	"	"	1 5 50	1 9 58
15	III.	"	Full brightness	"	"	1 17 21	
19	I.	Ecl. D.	Began to fade	"	140	23 44 13	23 46 27
19	I.	"	Last seen	"	"	23 47 23	
22	III.	"	Began to fade	"	"	3 22 17	3 31 1
22	III.	"	Last seen	"	"	3 36 14	
22	III.	Ecl. R.	First seen	"	"	5 5 5	5 8 20
22	III.	"	Full brightness	"	"	5 17 8	
24	II.	Occ. R.	First seen	"	"	23 28 43	
24	II.	"	Bisection	"	"	23 30 39	23 30
24	II.	"	Last contact	"	"	23 32 14	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
April 27	I.	Tr. Ingr.	Ext. contact	8-inch	170	23 17 7	
27	I.	„	Bisection	„	„	23 19 2	23 19
27	I.	„	Int. contact	„	„	23 21 46	
28	I.	Occ. R.	First seen	„	„	22 48 10	
28	I.	„	Bisection	„	„	22 48 58	22 50
28	I.	„	Last contact	„	„	22 50 7	
May 1	II.	Ecl. D.	Last seen	„	140	22 25 33	22 25 51
5	I.	„	Began to fade	„	„	22 1 9	22 2 18
5	I.	„	Last seen	„	„	22 3 3	
6	I.	Tr. Egr.	Ext. contact	„	„	21 41 47	21 41
13	I.	Tr. Ingr.	Int. contact	„	„	21 17 42	21 14
13	I.	Tr. Egr.	Int. contact	„	110	23 20 47	
13	I.	„	Bisection	„	„	23 22 36	23 25
13	I.	„	Ext. contact	„	„	23 24 46	
17	II.	Tr. Ingr.	Ext. contact	„	170	22 50 41	
17	II.	„	Bisection	„	„	22 52 46	22 53
17	II.	„	Int. contact	„	„	22 55 35	
18	II.	Tr. Egr.	Int. contact	„	„	1 14 7	
18	II.	„	Bisection	„	„	1 16 7	1 19
18	II.	„	Ext. contact	„	„	1 18 51	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of Nautical Almanac.
						h m s	h m s
May 20	I.	Ecl. D.	Last seen	8-inch	130	1 50 45	1 50 9
20	III.	Occ. R.	Last contact	„	95	21 7 36	21 3
20	I.	Tr. Ingr.	Ext. contact	„	170	22 55 43	
20	I.	„	Bisection	„	„	22 57 43	22 58
20	I.	„	Int. contact	„	„	22 59 57	
21	I.	Occ. D.	First contact	4½-inch	120	20 15 54	
21	I.	„	Bisection	„	„	20 17 39	20 17
21	I.	„	Last seen	„	„	20 19 3	
21	I.	Occ. R.	Bisection	8-inch	170	22 26 49	22 28
21	I.	„	Last contact	„	„	22 27 57	
June 9	II.	Occ. D.	First contact	„	130	23 41 18	
9	II.	„	Bisection	„	„	23 43 38	23 45
9	II.	„	Last seen	„	„	23 46 12	
12	I.	Tr. Ingr.	Ext. contact	„	„	22 35 54	
12	I.	„	Bisection	„	„	22 37 38	22 37
12	I.	„	Int. contact	„	„	22 40 3	
13	I.	Occ. D.	First contact	„	„	19 54 10	
13	I.	„	Bisection	„	„	19 55 49	19 55
13	I.	„	Last seen	„	„	19 57 39	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
June 13	I.	Ecl. R.	First seen	8-inch	130	22 37 33	22 37 39
13	I.	"	Full brightness	"	"	22 39 42	
14	III.	Tr. Egr.	Bisection	"	"	20 20 19	20 30
14	III.	"	Ext. contact	"	"	20 31 42	
18	II.	Tr. Ingr.	Ext. contact	"	"	20 55 31	
18	II.	"	Bisection	"	"	20 58 51	20 58
18	II.	"	Int. contact	"	"	21 2 30	
18	II.	Tr. Egr.	Int. contact	"	"	23 22 7	
18	II.	"	Bisection	"	"	23 25 36	23 26
18	II.	"	Ext. contact	"	"	23 30 40	
21	I.	"	Int. contact	"	"	20 56 31	
21	I.	"	Bisection	"	"	20 58 56	21 2
21	I.	"	Ext. contact	"	"	21 2 5	
21	III.	Tr. Ingr.	Ext. contact	"	"	21 59 16	
21	III.	"	Bisection	"	"	22 8 14	22 10
21	III.	"	Int. contact	"	"	22 17 43	
21	III.	Tr. Egr.	Int. contact	"	"	23 38 49	
21	III.	"	Bisection	"	"	23 45 58	23 55
21	III.	"	Ext. contact	"	"	23 54 47	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
June 22	I.	Ecl. R.	First seen	8-inch	75	19 0 57	19 0 41
22	I.	„	Full brightness	„	„	19 2 45	
25	II.	Tr. Ingr.	Ext. contact	„	170	23 16 1	
25	II.	„	Bisection	„	„	23 18 6	23 15
25	II.	„	Int. contact	„	„	23 20 21	
27	I.	Occ. D.	First contact	„	—	23 25 25	
27	I.	„	Bisection	„	—	23 28 29	23 27
27	I.	„	Last seen	„	—	23 30 9	
2	III.	Ecl. D.	Began to fade	„	75	19 6 53	19 12 5
2	III.	„	Last seen	„	„	19 16 42	
2	III.	Ecl. R.	First seen	„	„	20 53 24	20 58 2
4	II.	Occ. D.	First contact	„	170	19 50 14	
4	II.	„	Bisection	„	„	19 52 23	19 53
4	II.	„	Last seen	„	„	19 54 33	
July 5	II.	Ecl. R.	First seen	„	130	0 16 14	0 15 34
5	II.	„	Full brightness	„	„	0 20 39	
5	I.	Tr. Ingr.	Ext. contact	„	170	22 23 22	
5	I.	„	Bisection	„	„	22 25 17	22 24
5	I.	„	Int. contact	„	„	22 27 27	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
July 7	I.	Tr. Egr.	Int. contact	8-inch	95	19 0 49	
7	I.	,,	Bisection	,,	,,	19 3 14	19 4
7	I.	,,	Ext. contact	,,	,,	19 6 8	
9	III.	Ecl. D.	Began to fade	,,	,,	23 3 29	23 10 53
9	III.	,,	Last seen	,,	,,	23 15 12	
10	III.	Ecl. R.	First seen	,,	,,	0 53 24	0 57 49
10	III.	,,	Full brightness	,,	,,	1 2 9	
11	II.	Occ. D.	First contact	,,	130	22 11 50	
11	II.	,,	Bisection	,,	,,	22 15 34	22 17
11	II.	,,	Last seen	,,	,,	22 18 49	
13	II.	Tr. Egr.	Int. contact	,,	,,	19 34 15	
13	II.	,,	Bisection	,,	,,	19 38 0	19 37
13	II.	,,	Ext. contact	,,	,,	19 41 54	
13	I.	Occ. D.	First contact	,,	,,	21 28 21	
13	I.	,,	Bisection	,,	,,	21 30 51	21 30
13	I.	,,	Last seen	,,	,,	21 32 30	
15	I.	Ecl. R.	First seen	,,	75	19 13 9	19 12 59
15	I.	,,	Full brightness	,,	,,	19 14 47	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
July 20	II.	Tr. Ingr.	Ext. contact	8-inch	130	19 35 8	
20	II.	„	Bisection	„	„	19 36 58	19 31
20	II.	„	Int. contact	„	„	19 40 8	
20	II.	Tr. Egr.	Int. contact	„	„	22 2 9	
20	II.	„	Bisection	„	„	22 4 58	22 2
20	II.	„	Ext. contact	„	„	22 8 23	
20	I.	Occ. D.	First contact	„	„	23 17 56	
20	I.	„	Bisection	„	„	23 20 41	23 20
20	I.	„	Last seen	„	„	23 22 45	
21	I.	Tr. Ingr.	Ext. contact	„	„	20 29 2	
21	I.	„	Bisection	„	„	20 31 32	20 31
21	I.	„	Int. contact	„	„	20 34 41	
21	I.	Tr. Egr.	Int. contact	„	„	22 38 46	
21	I.	„	Bisection	„	„	22 42 5	22 44
21	I.	„	Ext. contact	„	„	22 45 19	
22	I.	Ecl. R.	First seen	„	„	21 7 24	
22	I.	„	Full brightness	„	„	21 11 18	21 7 40

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of Nautical Almanac.
						h m s	h m s
Aug. 22	III.	Ecl. R.	First seen	$4\frac{1}{2}$-inch	120	0 54 20	
22	III.	"	Full brightness	"	"	1 4 18	0 56 56
Sept. 15	III.	Tr. Egr.	Bisection	8-inch	140	22 6 26	
15	III.	"	Ext. contact	"	"	22 11 50	22 13
26	III.	Ecl. R.	First seen	"	"	20 54 59	
26	III.	"	Full brightness	"	"	21 5 33	20 57 32
28	I.	Tr. Ingr.	Ext. contact	"	230	21 19 37	
28	I.	"	Bisection	"	"	21 21 21	21 21
28	I.	"	Int. contact	"	"	21 22 56	
29	II.	"	Ext. contact	"	"	21 30 52	
29	II.	"	Bisection	"	"	21 33 37	21 29
29	II.	"	Int. contact	"	"	21 35 37	
29	I.	Ecl. R.	First seen	"	"	21 46 39	
29	I.	"	Full brightness	"	"	21 49 29	21 46 39
Oct. 1	II.	"	First seen	"	140	21 7 27	
1	II.	"	Full brightness	"	"	21 10 31	21 6 39

Remarks.

1888, March 27.—Sky cloudless, but with full Moon; objects low and unsteady.

April 2.—Clear. Images steady and well defined.

April 9.—Clear; fair definition.

April 14, 15.—Cloudless. Bad definition at the disappearance, but good at reappearance.

April 19.—Clear; definition satisfactory.

April 22.—Clear. Images remarkably steady and well defined. Satellites dwindled to a mere point and then vanished. Time of full brightness perhaps too early.

April 24, 27.—Images steady and well defined.

April 28.—Images steady and pretty well defined; when first seen the projection of the satellite from the limb was rather conspicuous.

May 1.—Definition pretty good, but sky slightly hazy.

May 5, 6.—Sky clear, but planet boiling. Noted time of external contact probably rather early.

May 13.—Planet low and badly defined at ingress, but steady and well defined at egress.

May 17, 18.—Images steady and well defined.

May 20.—Sky clear. Satellite I., which was steady and well defined, did not at the eclipse come quite into contact with the limb, but as it disappeared it assumed an elongated form, the major axis of the oval lying parallel to the limb. Planet low at the occultation and boiling considerably. Images steady and well defined at the transit.

May 21.—Planet boiling at the disappearance; images steady and well defined at the reappearance.

June 9.—Images steady and definition pretty good.

June 12.—Poor definition.

June 13.—Clear. Images pretty steady and well defined.

June 14.—Clouds troublesome and definition bad.

June 18.—Definition fair at ingress, but very bad at egress.

June 21.—Definition satisfactory at all the phases, except at bisection of III. at egress.

June 22.—Clear sky and good definition, but twilight strong, the Sun's upper limb having disappeared below the horizon 14 minutes previously.

June 25, 27.—Very good definition.

July 2.—Clear, but twilight very strong at disappearance; good definition at reappearance.

July 4, 5.—Clear, with good definition. Satellite at eclipse suspected 12·5 seconds earlier.

July 7.—Strong twilight; images tremulous and badly defined.

July 9, 10.—Clear. Images steady and well defined. Satellite again glimpsed 17 seconds after recorded as last seen.

July 11.—Images steady and well defined.

July 13.—Definition fair, but images tremulous.

July 15.—Clear, with good definition, but twilight very strong.

July 20, 21.—Fair definition.

July 22.—Clear, with good definition, but moon very bright.

Aug. 5.—Definition good, but bisections rather late. Eclipse observation unsatisfactory owing to a filmy cloud.

Aug. 6.—Clear. Images well defined.

Aug. 12, 13.—Poor definition at occultation of satellite I. Observation of the reappearance of II. from occultation difficult in consequence of the faintness of the satellite, which was probably involved to some extent in the planet's penumbra. Fair definition at egress of satellite I.

Aug. 20.—Bad definition.

Aug. 21, 22.—Clear, and definition pretty good except at the reappearance

of satellite III. Satellites I. and III. suspected 14 and 3 seconds earlier than the respective recorded times. Full Moon.

Sept. 15, 26.—Images steady and well defined.

Sept. 28. –Bad definition.

Sept. 29.—Clear, with bad definition.

Oct. 1.—Definition pretty good, but sky slightly hazy. Full brightness very unsatisfactory.

It may be added that no occulting-bar has ever been employed in the eclipse observations made at this observatory from 1866 to the present time, and that the times given in the first and seventh columns of the accompanying table are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20^s{\cdot}8$, and entered to the nearest second.

Windsor, N. S. Wales:
1889, *January* 8.

Request to Observers of Occultations. By John Tatlock, Jun.

(*Communicated by the Secretaries.*)

I should be obliged if those astronomers who secured observations of the occultation of *α Tauri* by the Moon, between the dates of 1884, September 10, and 1888, March 18, inclusive, will kindly send me copies of the records of such observations, together with full particulars essential to their reduction.

Care of North River Safe Deposit Company,
187 *Greenwich Street, New York.*

Report of the Work of the Melbourne Observatory during 1888. By R. L. J. Ellery, F.R.S.

During the year ending January 1, 1889, the meridian work with the transit-circle has been continued without interruption, and has included, besides the usual observations of the fundamental clock stars and close circumpolar stars, stars of the *Berliner Jahrbuch* which culminate sufficiently high to be well seen at Melbourne, stars to which the places of comets and small planets have been referred, and a list of stars selected by Dr. Gill for the reduction of his heliometer observations, as well as observations of *Iris* at opposition and a list of comparison stars; also to assist Dr. Gill. The number of R.A. observations was 3,154, and those for polar distance 1,571.

Very little work has been done during the year with the great reflector, on account of increasing tarnish of the mirrors, only 170 revisions of Herschel's nebulæ having been secured. Sixteen new nebulæ were catalogued, and three of Herschel's could not be found.

In June the telescope was dismantled and preparation made for repolishing the mirrors, involving a large amount of experimental work. One of the 4-foot mirrors was partially repolished in October, when it was found necessary to alter the arrangements of the machinery in order to facilitate testing the mirror-surfaces during the process of figuring and polishing. These alterations were not completed till midsummer, when the weather became too warm to continue the polishing with any prospect of success. Further work in this direction has therefore been deferred till after February.

Observations of Sawerthal's Comet (a 1888), of *Sappho* in April, and search for *Eucrate* in July and August were included in the extra-meridional work of the year.

Sun-pictures with the photoheliograph were obtained on 148 days only, as a considerable time was occupied in the alteration of the secondary magnifier to get rid of images of dust particles on the surface of the front lens which detrimentally disfigured the photographs.

The work in meteorology and terrestrial magnetism was continued as usual, including monthly determinations of the absolute elements of terrestrial magnetism and a continuous photographic register of variations.

The daily *Isobaric Chart of Australia and New Zealand* was issued regularly, as in former years.

A Meteorological Conference of the Directors of Australasian Observatories was held at the Melbourne Observatory in September, with the view of improving intercolonial meteorology, the following representatives attending:—H. C. Russell, B.A., F.R.S. (New South Wales); C. Todd, M.A., C.M.G. (South Australia); Hon. John Forrest, C.M.G. (Western Australia); Clement L. Wragge, F.R.G.S., F.R. Met. Soc. (Queensland); Capt. Shortt, R.N. (Tasmania); Sir James Hector, M.D., K.C.M.G. (New Zealand); Col. R. L. J. Ellery, F.R.S., F.R.A.S. (Victoria).

With the exception of the usual meteorological periodicals, no publications have been issued during the year. But the second *General Star Catalogue* and yearly *Catalogue of Separate Results of Transit Circle Observations for* 1880–85, to form vol. vii., will shortly appear.

A Seth Thomas precision clock was obtained in June last. Its performance so far has been very satisfactory.

Preparations are in progress for the erection of the photographic telescope now being constructed by Sir Howard Grubb for star-charting. The instrument will be similar to those being made by the same maker for Greenwich, Cape of Good Hope, Mexico, &c.

[The above Report arrived too late for insertion in the Annual Report of the Council.]

#MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. APRIL 12, 1889. No. 6

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

On the Photographs of the Corona at the Solar Eclipse of 1889, *January* 1. By Edward S. Holden, LL.D., Director of the Lick Observatory, Foreign Associate.

In the *Observatory* for March 1889, I have given a general account of the observations of the solar eclipse of January 1, 1889. I have also sent to the Royal Astronomical Society, in the name of the Lick Observatory, a positive copy on glass of one of the best negatives taken by Mr. Barnard of the Lick Observatory.

Since writing the letter in question I have been engaged in the preparation of a report on this eclipse, which will be printed by the University of California (of which the Lick Observatory is a part).

This report will contain the results of—

(*a*) Observations at the Lick Observatory (of the partial phase);
(*b*) Observations by the Lick Observatory field party at Bartlett Springs;
(*c*) Observations by an eclipse expedition sent out by the Amateur Photographic Association of the Pacific Coast;
(*d*) Observations by many other amateur observers.

One section of this report is nearly completed, and I have thought that it might be of interest to communicate this section (which deals with the representation of the coronal forms as obtained from photographs and drawings) in advance of the printing of the whole report, which may require several months for its completion. I therefore beg to present two careful drawings which I have made, and a portion of the section of the final report.

The drawings are: fig. 1—which I have compiled from the various photographs taken by Mr. Barnard of the Lick Observatory with an ordinary Clark achromatic of 3 inches' aperture and 49 inches' focus (stopped down to $1\frac{3}{4}$ inch); and fig. 2, which is a copy of the outer coronal forms only, as they are shown on two negatives taken with portrait cameras by Messrs. Ireland and Lowden of the Amateur Photographic Association. The figures speak for themselves; the section of the report follows immediately.

"*Diagrams of the Solar Corona from Photographs by E. E. Barnard of the Lick Observatory, and from Photographs by Messrs. Ireland and Lowden of the Amateur Photographic Association.*

"From the beautiful photographs of Mr. Barnard I have prepared the diagram or index map of the corona, which is given in fig. 1. One of Mr. Barnard's negatives was first copied in positive on glass, and a projection from this positive was thrown on a screen by a lantern. From this projection a careful drawing (Moon's diameter equal to $2\frac{3}{4}$ inches) was made. The positive was then examined by the transmitted light of a kerosene lamp through an opal glass shade under a magnifying glass, and the outlines obtained by projection were filled in. The parallel of declination, ecliptic, and vertex were then inserted from computations by Mr. Keeler. The Sun's axis is inclined $1^\circ 24'$ to the north and south line as drawn.

"It is necessary to say that in making this diagram no pictorial effect has been sought for. It was intended to show only the more important features and details exhibited in the negatives obtained by the Lick Observatory party. The fainter details shown in the diagram are, necessarily, relatively too plain. A number of the minor features are omitted to avoid confusing the drawing, and because they were not well seen on account of the small size of the original negatives (Moon's diameter equal $\frac{46}{100}$ inches). The principal features are numbered for convenience of reference, from 1 to 113. Near the lines extending from the centre of the Sun towards the east and west, I have placed a scale of minutes of arc, corresponding to the faint circles described about the Moon's centre. The diagram is least satisfactory in the region 35 to 38.

"We may say *à priori* that the phenomenon of the Sun's corona

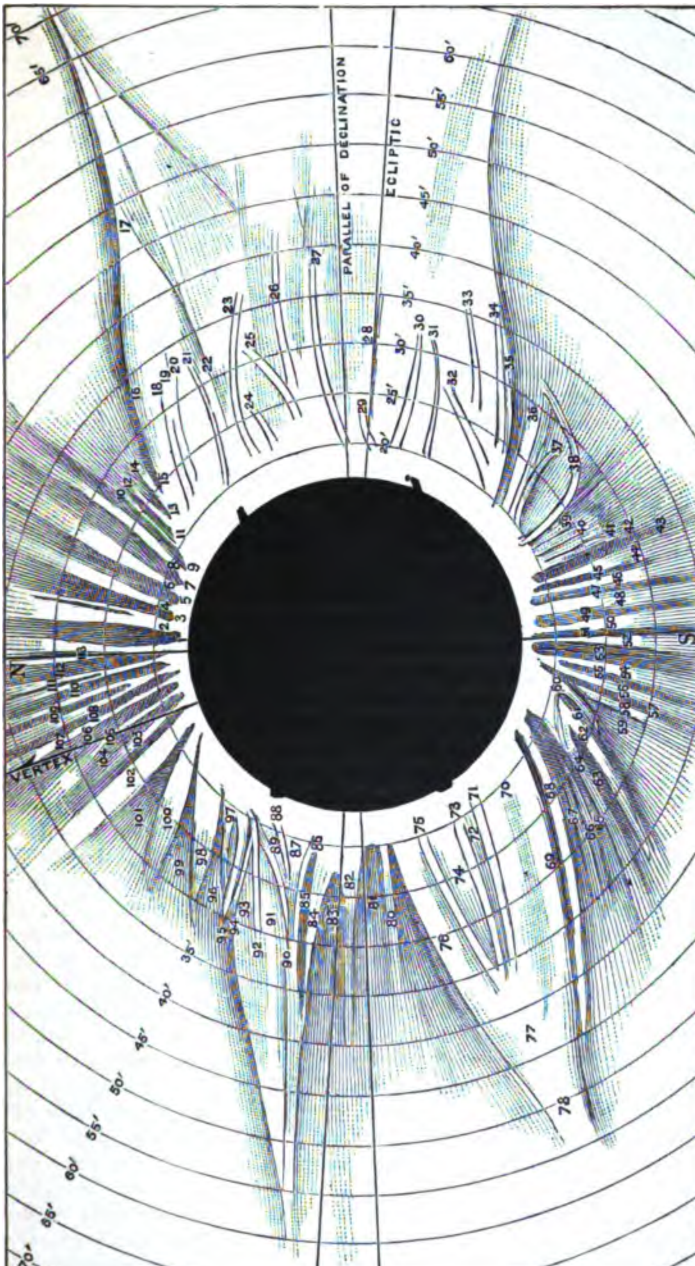


Fig. 1.—Diagram of the Solar Corona from photographs by E. E. Barnard, 1889, January 1.

is composed of at least three superposed appearances. There must be *first* some coronal effect due to diffraction &c. at the Moon's limb; *secondly* we have polar rays at the north and south poles of the Sun; and *thirdly* we have the equatorial wings or extensions. If we divide the phenomenon into parts by reference to brightness alone, and not simply as to structure, we have the inner corona (which is bright) and the outer corona (which is faint).

"Taking the corona as a whole, the first great result of the eclipse of 1889 is that *the characteristic coronal forms vary periodically as the Sun-spots (and the Auroras) vary in frequency.*

"Even a casual comparison of the drawings and photographs of 1889 with those of previous eclipses occurring at a period of minimum Sun-spots (the eclipse of 1867 and specially of 1878) shows that the characteristic forms of 1889 are typical of an epoch of minimum spots. The type for maximum spotted area is equally characteristic and very different. While there are minor features that vary from eclipse to eclipse, and do not seem to follow this law strictly, it appears that, broadly speaking, the eclipse of 1889 has established the correctness of the law above given, so far as our present data are sufficient. I believe that this law was first pointed out as probable by Mr. Ranyard (*Mem. R. A. S.*, vol. xli., 1879).

"We can best describe the parts of the corona as to extent and structure by reference to the index-map. The map shows the outer coronal wing at the south-east, extending as far as 78, or 55′ from the Moon's centre. At the north-west it extends fairly bright to 17, or 50′, and it can be traced to the 75′ circle by looking obliquely at the negatives, or by slowly moving them before a bright lamp with a porcelain shade. The south-west wing extends to the 50′ circle as fairly bright, and can be traced to 60′. The north-east wing, or ray, can be traced to 55′. All the important polar rays extend as much as 25′ to 30′ from the Moon's centre, and the longest ray (2) attains a length of 36′ in Mr. Barnard's best negative. There is little detail (except the four hydrogen flames) to be seen between the Moon's limb and the 20′ circle. It will be noticed that the south-west protuberance is in two distinct parts. A few of the narrow dark polar rifts (1, 3, 5, 7, 9, 43, 45, 47, 49, 51, 53, 57, 67, 69, 99, 101, 102, 103) end within the 20′ circle. The bright ring immediately around the Moon's limb may be in a small degree due to the chromosphere, but it seems likely that a certain portion of it, at least, is due to diffraction. The inner corona ceases to be bright at about 25′ in general, and in the wings 17, 30, 77, 92, the brightness falls off rapidly beyond the 30′ circle. A very curious feature of the best photographs is, that the coronal wings on the west side (20, 30) seem to have their north and south edges (16, 34) roughly parallel as far out as 45′ or 50′; while at this distance the edges (16, 17, 34) begin to diverge towards north and south respectively into a trumpet-like form. If the photographs are attentively

considered, they appear to show that the coronal beams inside the 50′ circle are gradually concentrating themselves. This seems to be their law as far as this point. It is therefore surprising to find at the 50′ circle the strongly marked tendency to divergent forms and to a trumpet-shaped extension. If the negatives did not show any portion of the wings beyond 45′ or 50′, it would be at once concluded from them that these extensions were convergent. But from the 50′ circle outward to 65′ and 75′ (on the west side of the Sun) the lines (16, 17, and 34) become strongly divergent, so that at the 65′ circle their distance apart (north and south) is already something like 45′.

"When I first discovered this in Mr. Barnard's negatives, I was inclined to doubt the position of the faint edges (16, 17, and 34), which I had laid down from the photographs, and I therefore sought for some evidence from the many drawings which had been sent to the Observatory for discussion.

"The drawings of Miss Robertson at Cloverdale, Mr. Staples at Bartlett Springs, Miss Silvia Rey at Cloverdale, Miss Nellie Treat at Cloverdale, Mr. C. Mason Kinne at Cloverdale, clearly indicate something of the trumpet-like extension referred to on the west side of the corona. In particular the sketch of Miss Treat shows an extension of the south edge of the south-west wing extending to 89′ from the Moon's centre. These drawings were all made without hiding the inner corona from the eye. The drawing of Miss Treat in particular agreed beautifully in direction with the line (34) of the photographs. The divergent character of the coronal wings on the west side of the Sun is completely proved by the photographs and by the drawings referred to, and the line (35, 34) can be drawn as far as 65′ with no doubt whatever, and with considerable confidence as far as 89′ from these two authorities alone. Fortunately for the question, the Observatory possesses a large number of photographs made by the members of the Amateur Photographic Association (see the reports in Part III.). A large number of these yield important evidence on the question of the extension of the outer corona, especially those of Messrs. Lowden, Ireland, Dornin, Treat, Passavant, Grimwood, and Burckhalter. Two of them, however, made by Mr. Lowden and by Mr. Ireland respectively, are so remarkable and so conclusive that we need only consider these two in order to obtain an entirely satisfactory portrayal of the outer coronal beams. It must be remembered that no previous photograph of the corona has extended beyond 50′ from the Sun's centre, so far as I know, and we are now concerned only with the description of the corona beyond the circle of 65 minutes. As I have said, the photographs of Mr. Barnard, together with the drawing of Miss Treat, carry the outlines of the outer corona out beyond the 80′ circle. The photographs of Mr. Ireland and Mr Lowden are naturally wanting in detail near the Sun, but beyond the 60′ circle they seem to carry the outlines of the four coronal wings as far as 135′ and 165′ respectively.

Fig. 2.—Diagrams of the Outer Corona, 1889. Jan. 1, from photographs by Messrs. Ireland and Lowden.

" The shortest way to present the evidence of these pictures is to copy their main outlines, which I have done in fig. 2. The scale is different for the two figures, but the circles concentric with the Moon's centre will serve as means of comparison. The

copies have been made from positives (and are reversed north and south from the index-map of Mr. Barnard's pictures, as all measurements with the compasses had to be made on the glass, and not the film-side). A very summary examination of the pictures will show plainly that the wings *certainly* extend as follows:

	Ireland	Lowden.
The north edge of the N.W. wing	96′	83′
The south edge of the S.W. wing	94′	79′
The axis of the S.E. wing	69′	69′
The axis of N.E. ray or wing	79′	76′

Mr. Lowden's second plate (21 secs.) gives these distances, to which the wings are obvious, as 89′, 69′, 66′, 85′ respectively.

"If the pictures are held obliquely in a strong soft light, or moved gently in front of such a light, these limits are very much extended, and I am satisfied that the drawings in fig. 2 would be verified by anyone who will give the requisite attention. The appearance of the planet *Mercury* on Mr. Lowden's plates shows that the camera (which was kept pointed by hand by means of a finding telescope) did not follow the Sun exactly. In spite of this fact the extension of the outer corona is extremely great, as we have seen. If this camera had been accurately driven by clockwork we should have had even more detail and extent than they now show, remarkable as this is. It should be said that Mr. Ireland's 'D' shows the detail of the polar rays and of the inner corona much better than the others (where these were lost by imperfect driving of the camera during the long exposures), and it accordingly seems that Mr. Ireland's experiments as to light, exposure, plates &c. should be repeated at some future eclipse. It thus appears that the new feature of the corona which just begins to show plainly in the photographs by Mr. Barnard, and in the drawing of Miss Treat, is very satisfactorily portrayed in the negatives taken by Messrs. Lowden and Ireland at different places and with different instruments. Many other negatives by members of the Pacific Coast Amateur Photographic Association lend independent corroboration to the conclusion already drawn. I may also cite a beautiful negative by the Rev. Father Charroppin, which extends nearly as far, is full of detail, and entirely confirms the existence of the trumpet-shaped extension of the outer corona. It is worthy of note that the drawings of the outer corona by Professors Newcomb and Langley at the solar eclipse of 1878, which show the outer corona extending several degrees on each side of the Sun, present no evidence of the branching forms shown in the negatives just described.

"There is no connection proved by this drawing between the prominences and the streamers, and a direct connection of this kind is probably *à priori* unlikely. It must, however, be said that the four chief prominences visible are at or very near the bases of characteristic coronal forms as they appear in the drawing.

"There are a few constantly recurring types of coronal structure. The polar rays exhibit the most pronounced type, perhaps. At the North Pole the bright rays (98, 100, 102, 103, the lower part of 105, 108, 110, 111, 113; 2, 4, 6, the lower part of 8, &c.) are essentially of one type. They extend nearly radially near the poles with a tendency to be convex towards the Sun's axis prolonged to the north. 105 is curved and convex to the axis, while 8 is strongly concave in all of Mr. Barnard's negatives. (This is quite different in the Harvard College positive, which has been kindly presented to the Lick Observatory by Mr. W. H. Pickering. I have drawn Prof. Pickering's attention to this difference, and a careful examination of the negatives of the Harvard College and the Lick Observatories will be made to decide whether in fact one of the coronal forms changed its shape between the instants corresponding to our respective negatives.)

"Many of the bright polar rays are doubled, as 109, 111, 113, 2, &c. The doubling in many cases does not appear to be due to a perspective projection of one ray upon another, but, so far as mere looks are concerned, the duplicity appears to be structural. We must of course imagine the whole area of the Sun's surface near the poles to be bristling with a network of these radial beams, whose analogy to the Auroral beams on the Earth is most marked. At the south pole of the Sun the same type occurs in 68, 67, 64, 62, 58, 56, 54, 52, 50, 48, 46, 44, 42, 41, 40, 39, 38, 37 (which has contrary curvature), 36, 35, &c. The centre of radiation of each set does not appear to be at the Sun's centre. The dark rifts between the bright rays are usually fairly straight in general direction. Their sides are not rectilinear, however, when attentively examined, and their roots are singularly terminated (notably in the case of 1). The bright polar rays projected near the south pole are in general straighter than those at the north (which was turned away from the Earth on January 1).

"I have said, in what precedes, that we must conceive the whole surface of the Sun near the two poles to be bristling with these Auroral (?) streamers, and this is the usual view of the matter. I see no reason, however, for supposing that such rays are confined to regions near the two poles. On the other hand the rays, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, on the west side of the Sun, and 80, 82, 94, 95, 97, 98 on the east side, appear to me to be of the same general nature as the bright polar rays. They are nearly always curved (though 80 and 82 are marked exceptions), and in general they are curved towards the Sun's equator. If we examine the lines of force at the poles of a bar-magnet there is no discontinuity between the families of rays at the ends of the magnet and those at the sides; and in the case of the Sun also, the so-called 'polar' rays appear to extend all around the disc. There is no latitude at which we can say that here the polar rays end, and a new species—equatorial rays

—begins. For example, 58 is a polar ray; so is 64; so, it seems to me, is 80 in all but situation. Again, what is to distinguish 6, 8, 10, 12, 14 (which are all of the polar type), from 23, 25, 26, except their curvature and their situation?

"The equatorial rays are all projected, it must be remembered, on a bright background, which does not exist at the poles. If this background were removed, we should, I think, at once see that the typical polar rays do in fact extend all round the disc, being least plentiful at the solar equator. I would therefore consider that the first characteristic type of structure consists of rays ordinarily called 'polar,' which are not connected with any bright background, and of such others (as 80 and 82 for example) as have no connection with the wing-like extensions.

"It is clear that there is a second type of rays which are connected with the wing-like forms. The best examples of these are 71, 73, 75, 84, 86, 88, 90, and probably 18, 19, 20, 21. These give the peculiar striations to the wings. A very interesting recurrence of a type is shown in the cases of 23, 24, 25; 36, 37, 38, and 86, 88, 90, and perhaps at 60, 61, 62. The symmetric arrangements of these groups is noteworthy. It is interesting also to observe that the two darkest and narrow polar rifts are nearly opposite to each other. I have found no cases of curved rays which bend completely over as in Mr. Wesley's diagram of the eclipse of 1871 (*Monthly Notices R.A.S.*, vol. xlvii. p. 501).

"As is well known, the solar spots occur chiefly in two zones extending from 5 to 40 degrees of solar latitude, north and south. A few spots occur near the solar equator, none beyond 45 degrees of latitude. Carrington's observations (1853–1861) show the greatest number of spots to be in latitudes 20° N. and S. Spoerer's observations (1861–1867) show the greatest numbers in latitudes 10° N. and S. The wings of the corona of 1889 have their axes about as follows, if we suppose them to lie in the plane perpendicular to the line of sight:

NW.	wing,	axis in latitude	48° N.
S.W.	,,	,,	14 S.
S.E.	,,	,,	28 S.
N.E.	,,	,,	20 N.

"It is possible that the connection of such wing-like extensions with the zones of maximum spots has been too hastily assumed. . . ."

The Trapezium of Orion. By S. W. Burnham, M.A.

Perhaps no object in the sidereal heavens has received more attention from astronomers than the multiple star *θ Orionis.* It has been the subject of careful study by the most eminent observers, provided with the best astronomical instruments; and the relative positions of the principal stars have been determined with the greatest possible accuracy. Certainly no equal area in any other part of the sky has furnished room for the location of so many purely imaginary stars. At intervals during the last fifty years various observers have recorded a number of stars in the space enclosed by the four bright stars of the trapezium. As a rule these alleged discoveries have been made with small telescopes, even down to four inches' aperture, and by observers with little or no experience in double-star work. As would be expected, perhaps, in an object as carefully studied as this has been for the last twenty or thirty years, all the large and most perfect modern refractors, directed by the most experienced double-star observers, have utterly failed to show, under the best atmospheric conditions, the least trace of a single one of the dozen or more supposed new stars. The great 26-inch at Washington, until recently the most powerful telescope in the world, revealed nothing to Hall in the course of a long series of measures of the known stars of this group. The other large telescopes in this country—the McCormick 26-inch, the Princeton 23-inch, the Chicago 18½-inch, the Madison 16-inch, and the Harvard 15½-inch—were equally unsuccessful.

The trapezium was carefully examined by me with the Chicago telescope, at times under very favourable circumstances, and as the result of the search for the new stars (*Mem. R.A.S.* vol. xliv. p. 99) I stated:—

"Several observers have seen, or believe they have seen, minute stars in the trapezium. . . . While making the measures given above, and at other times, under very favourable conditions, the interior of the trapezium and the vicinity of the principal stars were carefully examined. There was not the slightest suspicion of any additional stars. If the sixth star itself had been double, with a distance of 1″, it could not have been overlooked. I have very little faith in the real existence of these suspected stars after the failure of this and other large refractors to show them. It is wholly improbable that they should be variable in such a manner as to render them at all times invisible within the last few years. In regard to the alleged variability of the fifth and sixth stars, I can only say that they have always been readily seen with my 6-inch in the last six years when the atmospheric conditions were suitable. So far as my observations go there appears to be no evidence of change in the light of these stars."

Hall, after giving an elaborate series of measures of the principal stars (*Washington Observations*, 1877), states, "During my observations I never saw any star within the trapezium, and several careful examinations were made."

And yet one observer with a 12-inch mirror has recorded, "In the trapezium nine stars certainly, ten probably, were visible;" all of which is sufficiently indefinite to anticipate any real discovery now or hereafter. In fact it would be impossible to place a star within the trapezium which could not be claimed as identical with some of the stars referred to.

It is not difficult to understand how, in a region of this character, with a nebulous background, and surrounded by bright stars, faint points of light might be suspected; but it is past comprehension that the observer, before making any announcement, should not satisfy himself by repeated observations of the actual existence of the suspected stars, and, having done that, should not have attempted to fix their places by some tangible evidence. Apparently there has never been any effort to determine their positions by micrometrical measures, and we have only diagrams and descriptions, more or less vague, from which to locate the suspected objects. Examples of this kind are found in the imaginary companions to *Vega*, *ε Lyræ*, *Polaris*, *Sirius*, &c., which have long been known to be purely mythical. Mr. Sadler has carefully compiled the observations relating to new stars within the trapezium (*English Mechanic*, Jan. 13, 1882), and given in a diagram, as accurately as possible, the places of the several stars.

When the 36-inch refractor of the Lick Observatory was mounted, one of the first objects examined by Mr. Alvan G. Clark, the maker of the object-glass, was the trapezium of *Orion*; and he detected at once an exceedingly faint point of light within the trapezium, and nearly equidistant from the large stars C and D. Since that time this star has been repeatedly seen and measured by me, and, although a difficult object with the great telescope, there is certainly no doubt of its reality. It is not very far from the limit of a 36-inch aperture, and can only be seen with this instrument in a very good, steady air. It will stand very little magnifying, and is best seen with the lowest micrometer eye-pieces, powers 390 and 450. I have called the magnitude of this star 16, but I think the brightness is really over-estimated, the limit of the instrument being 17·0 on Argelander's scale. I have never seen with this or any other telescope so faint a star, or one so difficult to measure. It would be overlooked by any but the most careful observer even with this telescope on the very best nights, and is absolutely invisible to me when the seeing is not first class.

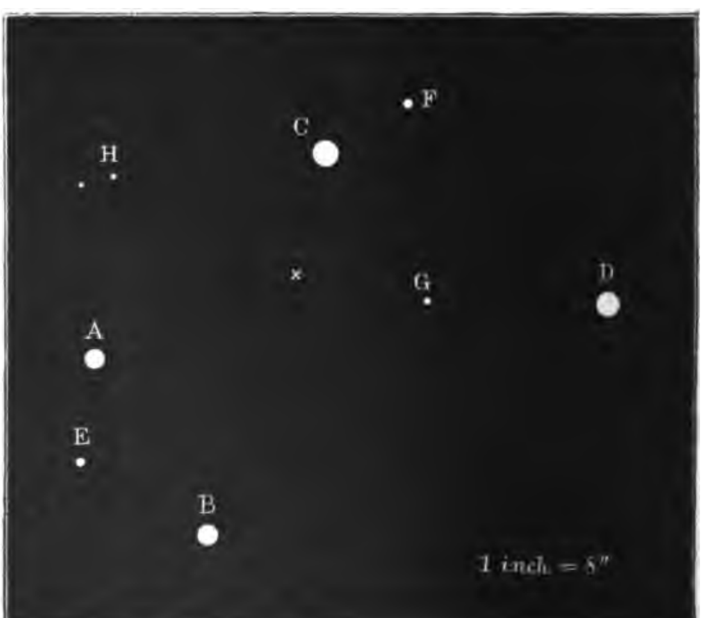
In October of the past year Mr. Barnard, of this Observatory, detected another new star just preceding the trapezium, which had been missed by all who had examined it with this telescope. It is about the same magnitude as the Clark star, and quite as

difficult to measure. He also saw that this exceedingly faint star was itself double, but I was unable to see the two components on any night when it was measured from the bright stars of the trapezium. Later, and on a remarkably perfect night, I saw the minute pair well, though with great difficulty, and obtained a fairly good measure. As a double star it is quite unlike anything known in the heavens, and the severest possible test for the defining and illuminating power of the large telescope. I have only been able to see it once.

No one who had seen either the Clark or the Barnard star with this instrument would for a moment doubt that they are beyond the reach of all other large telescopes. Possibly the Nice 30-inch may show them, but, from the difficulty of the observations here, I think it very improbable. The 30-inch at Pulkowa may be too far north.

Mr. Barnard has also discovered a second star within the trapezium, more centrally placed than the other, of the existence of which he has no question, having seen it on two occasions. I have not satisfactorily seen this star, and cannot speak of it from personal knowledge, but, from Mr. Barnard's great experience in studying very faint objects and his remarkable acuteness of vision, I am confident this new star will be found where he saw it, nearly on the diagonal from B to C. Down to this time I have found no night perfect enough to deal with it. It is certainly very much fainter than either of the other stars.

The accompanying diagram, drawn to scale (1 inch = 8″), will



indicate the relative positions of the several stars as derived from my measures. The unmeasured new star is indicated by a small cross.

The following measures were made by me with the 36-inch. The faint stars were usually measured with a power of 450, and the brighter stars with 670 and 1030. The Struve letters are used for the bright stars, the new stars being represented by the succeeding letters, and their magnitudes by the numbers in the fourth column :—

C and G. (Clark's star.)

1888·856	31°·7	7″·66	
1888·928	32·7	7·31	 16
1889·049	37·9	7·81	
1889·077	32·6	6·83	 16
1888·98	33·9	7·40	

D and G.

1888·856	273·1	7·45
1888·928	267·9	7·12
1889·049	272·1	6·56
1889·077	269·1	6·99
1888·98	270·5	7·03

A and H. (Barnard's star.)

1888·928	178·6	7·74	 16
1889·077	178·2	8·14	 16
1889·00	178·4	7·94	

C and H.

1888·928	275·1	9·17
1889·049	276·1	8·41
1889·077	275·7	8·29
1889·02	275·6	8·62

H[1] and H[2]. (Barnard's pair.)

1889·073	274·0	1·32	. . . 16...16·5

Excessively difficult.

A and B.

1888·862	31·8	8·66
·879	32·3	8·86
·895	32·7	8·70
1888·88	32·3	8·74

A and C.

1888·862	131°·5	13″·00
·879	131·2	13·06
·895	131·1	12·79
1888·88	131·3	12·95

D and C.

1888·856	241·7	13·23
·862	241·1	13·48
·879	241·1	13·35
1888·87	241·3	13·35

D and B.

1888·862	299·4	19·35
·879	299·4	19·33
·895	299·7	19·50
1888·88	299·5	19·39

B and C.

1888·862	162·9	16·87
·879	163·3	16·70
·895	162·7	16·71
1888·88	163·0	16·76

A and D.

1888·862	95·3	21·57
·879	95·5	21·55
·895	95·4	21·54
1888·88	95·4	21·55

A and E. (Fifth star.)

1888·862	352·0	4·28
·879	352·4	4·30
·895	350·1	4·36
1888·88	351·5	4·31

C and F. (Sixth star.)

1888·854	121·3	4·05
·856	121·8	4·06
·862	119·5	3·86
1888·86	120·9	3·99

As a test of the consistency, if not the accuracy, of the measures of position-angles, the following may be of some interest:—

Trapezium ABCD.

Angle A =	99°·0
B =	92·8
C =	110·0
D =	58·2
	360·0

Triangle ACD.

Angle CAD =	35°·9
ACD =	110·0
ADC =	34·1
	180·0

Triangle ADB.

Angle BAD =	63·1
ABD =	92·8
ADB =	24·1
	180·0

Triangle CDG. (Clark's star.)

Angle DCG =	27°·4
CDG =	29·2
CGD =	123·4
	180·0

Triangle ACH. (Barnard's star.)

Angle CAH =	47°·1
ACH =	35·7
AHC =	97·2
	180·0

The absence of any sensible change in the relative positions of the principal stars will be apparent from a comparison of these with the earlier measures of Struve and others. The number of nights of observation is given in the fourth column.

A and B.

1836·15	31°·6	8″·71	3n	Struve.
1873·69	31·8	8·61	2n	O. Struve.
1878·17	33·5	8·80	6n	Hall.
1888·88	32·3	8·74	3n	Burnham.

A and C.

1836·15	131·6	13·00	3n	Struve.
1868·20	132·4	13·25	5n	O. Struve.
1878·14	130·7	13·20	7n	Hall.
1888·88	131·3	12·95	3n	Burnham.

D and C.

	°	"		
1836·15	240·3	13·34	3n	Struve.
1868·20	241·8	13·41	5n	O. Struve.
1878·16	241·5	13·41	7n	Hall.
1888·87	241·3	13·35	3n	Burnham.

D and B.

1836·15	299·4	19·23	3n	Struve.
1873·69	300·2	19·29	2n	O. Struve.
1878·17	299·2	19·39	6n	Hall.
1888·88	299·5	19·39	3n	Burnham.

B and C.

1836·15	162·1	16·85	3n	Struve.
1868·20	163·6	16·89	5n	O. Struve.
1878·16	162·5	16·77	7n	Hall.
1888·88	163·0	16·76	3n	Burnham.

A and D.

1836·15	95·4	21·41	3n	Struve.
1872·20	95·2	21·40	3n	O. Struve.
1878·17	95·6	21·67	7n	Hall.
1888·88	95·4	21·55	3n	Burnham.

A and E.

1832·53	353·6	3·86	7n	Struve.
1859·62	350·8	4·29	4n	O. Struve.
1877·10	351·5	4·21	4n	Hall.
1888·88	351·5	4·31	3n	Burnham.

C and F.

1846·66	125·9	3·28	2n	Struve.
1858·85	128·8	3·93	5n	O. Struve.
1877·10	120·	4·00	4n	Hall.
1888·86	120·9	3·99	3n	Burnham.

The trifling differences in the measures of the fifth and sixth stars are undoubtedly due to errors of observation. As a multiple star it is wholly wanting in interest so far as relative motion is concerned.

Mount Hamilton :
1889, *March* 1.

Probable Errors of Greenwich Determinations of Right Ascension at different Zenith Distances. By A. M. W. Downing, M.A.

The observations used in computing these probable errors are chiefly those made in the years 1886 and 1887. In some of the groups observations made in 1885 have also been included. For the close polar stars, which are used for determination of the azimuth error of the Transit-Circle, the observations made in the years 1880–87 have been utilised, in order to get a sufficient number of observations of each star. As these stars were observed by the eye-and-ear method, the results for them are placed in a separate table, as not being comparable with the results obtained for stars observed by the chronographic method. In Table II., giving the results for south stars, I have added, for comparison, the probable errors computed by Mr. Dunkin from the Greenwich observations for 1857, printed in the *Monthly Notices*, vol. xx. p. 88. In the case of *Polaris* (Table III.) it was found that the probable errors deduced from the observations in 1885–87 were distinctly smaller than those found for the other azimuth stars from the observations made in 1880–87. It was thought that this might possibly arise from a change in the method of observing these close polar stars introduced at the beginning of 1885, viz. moving the system of vertical threads by means of the micrometer screw during the star's transit, so that a considerably greater number of separate observations could be obtained at the same transit than was formerly possible. The probable errors for *Polaris* were therefore computed afresh from the observations made in 1880–82, and these, although slightly larger than the former values, are still distinctly smaller than the values obtained for the other close polar stars. It would appear, therefore, that the determinations of right ascension of *Polaris* are more accurate (as estimated by discordance from the mean) than those of the other close polar stars which are used for determination of azimuth error. It will be remembered that the deduced right ascensions of these stars depend on azimuth errors determined from at least two consecutive transits of *Polaris* and *Polaris S.P.*, and are therefore independent of the assumed place of that star.

TABLE I.

Circumpolar Stars.

N.P.D. (Above Pole.)	Z.D. of middle of Zone.	P.E.	P.E. × sin N.P.D.	No. of Obs.
° °	°	s	s	
50–45	9	±0·044	±0·032	131
45–40	4	·038	·026	135
40–35	1	·040	·024	134
35–30	6	·050	·027	136
30–25	11	·079	·036	133
25–20	16	·101	·039	86
20–15	21	·092	·028	74
15–10	26	·146	·032	53
10–5	31	·165	·022	26
(Below Pole.)				
5–10	46	·189	·025	43
10–15	51	·150	·032	57
15–20	56	·107	·032	80
20–25	61	·087	·033	113
25–30	66	·074	·034	82
30–35	71	·063	·034	77
35–40	76	·064	·039	74
40–45	81	·065	·044	61
45–50	86	±0·056	±0·041	13

TABLE II.

South Stars.

N.P.D.	Z.D. (of middle of Zone).	P.E.	P.E. × sin N.P.D.	No. of Obs.	Dunkin's Results.
° °	°	s	s		s
50–55	14	±0·034	±0·027	135	±0·037
55–60	19	·044	·037	123	
60–65	24	·039	·035	135	·035
65–70	29	·041	·038	135	
70–75	34	·031	·030	135	·029
75–80	39	·035	·034	135	
80–85	44	·035	·035	135	·032
85–90	49	·031	·031	135	
90–95	54	·038	·038	135	·032
95–100	59	·035	·035	135	
100–105	64	·042	·041	134	·035
105–110	69	·037	·035	135	
110–115	74	·043	·040	133	±0·043
115–120	79	·048	·043	135	
120 +	84	±0·052	±0·044	98	

TABLE III.

Azimuth Stars.

Star.	Above Pole. P.E.	P.E. × sin N.P.D.	No. of Obs.	Below Pole. P.E.	P.E. × sin N.P.D.	No. of Obs.
	s	s			s	
λ Ursæ Minoris	± 1·643	± 0·030	89	± 1·449	± 0·027	54
Polaris (1880–1882)	0·881	·020	135	0·985	·023	135
Polaris (1885–1887)	·824	·019	132	·827	·019	132
Cephei 51	·713	·035	59	·636	·031	102
δ Ursæ Minoris	± 0·482	± 0·028	111	± 0·537	± 0·032	52

The probable errors given above have been computed by taking the difference between each separate result for right ascension and the mean result for the year, as given in the "Ledger" section in the volumes of *Greenwich Observations*. From the squares of these differences the probable errors have been found by the usual formula.

Blackheath: April 1889.

On the Proper Motion of 85 *Pegasi.* By J. E. Gore.

Using Mr. Burnham's measures of the 9th magnitude comparison to this rapid binary star, in the years 1878–88, I have computed the following formulæ:

$$\rho^2 = 194{\cdot}0449 + 1{\cdot}491\,(t - 1874{\cdot}92)^2,$$
$$\sec\,(51^\circ{\cdot}25 - \theta) = 0{\cdot}0718\rho.$$

The following is a comparison between the measures and the positions computed from the above formulæ:—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
1870·00	Brünnow	77°·0	74°·77	+2°·23	16″·0	15″·17	+0″·83
1878·54	Burnham	33·6	33·67	−0·07	14·40	14·61	−0·21
1879·27	"	30·4	30·42	−0·02	14·96	14·91	+0·05
1880·57	"	25·0	24·91	+0·09	15·41	15·54	−0·13
1881·54	"	20·8	21·13	−0·33	16·29	16·10	+0·19
1882·77	"	17·1	16·70	+0·40	17·34	16·91	+0·43
1883·537	Seagrave	11·27	14·37	−3·10	17·34	17·45	−0·11
1888·69	Burnham	0·9	0·90	0·0	21·71	21·83	−0·12

The annual proper motion of the binary pair is therefore 1″·221 in the direction of position-angle 141°·25.

On an Error in Brünnow's Formulæ for Differential Refraction in Distance and Position-Angle. By W. H. Finlay, M.A.

My attention was recently drawn to the fact that the formulæ given by Brünnow and by Chauvenet for the differential effects of refraction on distance and position-angle do not agree, and on investigation I found that there is an error in Brünnow's formulæ.

After finding expressions for the differential refractions in right ascension and declination, he proceeds to deduce those in distance (Δ) and position-angle (π) by help of the formulæ

$$\left.\begin{aligned}\cos\delta(\alpha-\alpha') &= \Delta\sin\pi\\ \delta-\delta' &= \Delta\cos\pi\end{aligned}\right\}$$

but in differentiating the first equation he treats δ as a constant.

If these equations be differentiated, treating δ as a variable and substituting $\kappa\tan\zeta\cos\eta$ for $d\delta$, it will be found that the expressions for refraction in distance and position-angle agree exactly with Chauvenet's formulæ.

Royal Observatory, Cape of Good Hope:
1889, *March.*

Photographs of the Nebulæ M 81, 82, *and a Nebulous Star in Ursa Major.* By Isaac Roberts.

The photographs were taken on March 31, 1889, with an exposure of 3½ hours. One is enlarged five times and the other fifteen times the negative, and they show that the nebula M 81 is of a spiral character, and so differs from the other nebulæ, which have been already photographed, and differs also from the written descriptions of it which have been published by Sir John Herschel and by the Earl of Rosse. Sir J. Herschel refers to it as a "remarkable object, extremely bright, extremely large, suddenly very much brighter in the middle, and with a bright nucleus." The Earl of Rosse confirms these statements, and adds that it extends about 8′ from the nucleus to the north and does not extend beyond the first two stars.

The photograph shows it to extend far beyond the two stars presumably referred to, and the negative shows that the nucleus, which has not a well-defined boundary, is surrounded by rings of nebulous or meteoric matter, and that the outermost rings are discontinuous in the n.p. and s.f. directions.

It is very noticeable that there are numerous stars, or, more probably, star-like condensations of the nebular matter, arranged symmetrically, and apparently incorporated with the rings. It

requires little stretch of the imagination, and we feel strongly tempted, to account for these extraordinary appearances by referring them to Mr. Lockyer's theory of the collision of streams of meteorites. In this case one stream would be coming from the n.p. and the other from the s.f. directions, the collision between them causing the formation of the dense and undefined nucleus as well as the vortex, as shown in the photograph.

The other explanation of the vortex would be that it is an optical illusion, caused by the outermost rings appearing discontinuous, owing to insufficient photographic power, either physical or instrumental, to show that the faint rings are continuous round the nucleus; but the vortex hypothesis seems at present to explain most satisfactorily all the appearances as they are presented on the photograph.

M 82.

This nebula is described by Sir John Herschel as a "beautiful ray," very bright, very large, and very much extended. Lord Rosse states it is a "most extraordinary object, at least 10′ in length and crossed by several dark bands."

The photograph, particularly the negative, shows it to be probably a nebula seen edgeways, with several nuclei of a nebulous character involved, and the rifts and attenuated places in it are the divisions of the rings, which would be visible as such if we could photograph the nebula from the direction perpendicular to its plane. We see it in section, and the upper and lower surfaces are very rugged, and suggest that the evolution of this stellar system has not proceeded so far as that of the *Andromeda* nebula; but I must refrain from pursuing further speculation, for we want fuller data.

Nebulous Star.

The star is in the s.f. quadrant, and is very bright. Shortly I shall be able to give to the Society the distances and triangulation of it and of the two nebulæ already described; but an important question has frequently arisen in my mind when examining this and several other nebulous stars that I have photographed in different parts of the sky. *Are they not the bright nuclei of nebulæ*, the rings around them being invisible to us by reason of either of the following conditions: 1st, condensation not having proceeded far enough to show the rings; 2nd, they may be too distant for us to see the rings; 3rd, greater optical power might show them, and we may hope that ere long the question may be satisfactorily answered by the means which are now available to us?

The photographs are placed in the Library.

A Catalogue of the Stars of the IV. Type. By T. E. Espin.

The following catalogue contains all the stars of type IV. known up to the present time. In addition to those given by Dr. Dunér (*Sur les étoiles à spectres de la troisième classe*, p. 22) there are those detected by Pechüle (*Expédition danoise pour l'observation du passage de Vénus*), by Konkoly (*Spectroskopische Beob. der Sterne zwischen* 0° *und* −15° *bis zu* 7·5*ter Grösse*), and by myself. The places have been brought up to 1890, and are taken (1) from *Dunsink Observations*, part iv., containing the "Mean Places of 321 Red Stars;" (2) from the D.M. and Südl. D.M.; and (3) from the *Catalogo General Argentino*. In a few cases the stars are not found in any catalogue of star places, and consequently the places must be considered as more or less approximate. The magnitudes are from the D.M. and Südl. D.M., and for stars still farther south from the *Catalogo General Argentino*, and when the star is in none of these from the original observations. In passing I may note that the magnitudes of red stars as seen in the 17½-inch Reflector are higher than those of the D.M. In column five the following abbreviations are used: Secchi=Se.; D'Arrest=D'A.; Vogel=V.; Pechüle=Pe.; Pickering=Pi.; Dunér=Du.; Konkoly=K.; while my own observations are marked Es.

The mean magnitudes of the stars observed are as follows:—

Secchi*	...	...	6·7
D'Arrest*	..	...	7·0
Vogel*	...	...	7·1
Pechüle	...	...	7·3
Pickering	...	...	8·4
Dunér*	...	...	8·3
Espin	...	...	8·8

Of the 113 stars 29 only are south of the Equator. This, on the supposition of equal distribution in the northern and southern hemispheres, would make a total of 168 stars of type IV. in the whole heavens above the mean magnitude of 8·8. The number of them may be considered as fairly complete down to −21°, since from the Catalogue it will be found that from +0° to +21° there are 21, and from −0° to −21° there are 21. Many of the stars in the Catalogue are variable to the extent of a magnitude and with no regular period. The leading star of this class of variable is 19 *Piscium*.

* Dunér, *Sur les étoiles*, &c., p. 125.

No.	Schj., D.M., &c.	α 1890 h m s	δ ° ′	Mag.	Auth.	Note.
1	Schj. 3	0 14 5	+44 5·9	8·2	Du.	
2	+34°·56	21 42	+34 59·7	8·1	Du.	
3	+57°·165	48 22	+57 57·9	9·5	Es.	
4	Schj. 7	1 10 5	+25 11·3	7·0	D'A.	
5	Es. 230	26 27	+57 11·2	9·8	Es.	
6	+51°·575	2 19 12	+51 34·1	9·0	Es.	
7	+56°·724	42 22	+56 31·5	9·4	Du.	
8	+57°·647	42 51	+57 23·7	8·9	Du.	
9	+57°·702	3 2 57	+57 29·1	7·9	Pi.	
10	+47°·783	6 1	+47 26·5	9·0	Es.	
11	Schj. 27*a*	32 21	+62 17·5	7·0	Du.	
12	+61°·667	56 18	+61 32·0	7·5	Es.	
13	Schj. 41	4 39 49	+67 58·4	7·0	Se.	
14	+21°·702	41 14	+21 57·8	9·4	Es.	
15	+34°·911	41 59	+34 48·4	8·8	Es.	
16	+15°·691	44 19	+15 36·4	9·4	Es.	
17	Schj. 43	44 38	+28 20·3	8·1	Se.	
18	+38°·955	45 6	+38 18·9	8·8	Es.	
19	+22°·770	47 12	+22 35·5	9·2	Es.	
20	R Leporis	54 36	−14 58·3	var.	V.	
21	+38°·1010	55 48	+38 54·6	9·5	Es.	
22	Schj. 51	59 43	+ 1 1·5	6·0	Se.	
23	−5°·1174	5 3 24	− 5 39·3	8·7	Du.	Birm. 99
24	+35°·1046	11 48	+35 40·4	8·9	Es.	
25	+32°·957	14 49	+32 23·7	9·3	Es.	
26	S Aurigæ	19 51	+34 3·2	var.	Du.	
27	+7°·929	27 17	+ 7 3·8	8·2	Es.	
28	+68°·398	29 7	+68 44·3	9·3	Es.	
29	Schj. 64	38 29	+24 22·3	8·5	Du.	
30	Schj. 64*a*	39 6	+20 38·9	7·7	Du.	
31	Schj. 65	40 10	−46 30·2	7½	Pe.	
32	Schj. 64*c*	41 3	+30 35·4	8·5	Es.	
33	Schj. 72	6 4 3	+26 2·1	7·4	D'A.	
34	Schj. 73	6 38	+27 11·8	9·0	Du.	
35	+33°·1290	10 1	+33 14·6	9·1	Es.	
36	Es. 160	13 26	+47 44·6	8·7	Es.	
37	+3°·1214	16 36	+ 3 28·8	9·0	Es.	
38	+25°·1250	17 5	+25 4·2	9·5	Es.	
39	Schj. 74	19 12	+14 46 9	6·5	D'A.	

No.	Schj., D.M., &c.	α 1890 h	m	s	δ °	′	Mag.	Anth.	Note.
40	Es. 243	6	19	44	+19	9·7	9·4	Es.	
41	+3°·1381		38	54	+ 3	25·7	9·3	Pi.	
42	Es. 247		46	59	− 7	0·5	8·8	Es.	
43	+6°·1462		52	30	+ 6	18·8	8·0	Es.	
44	−3°·1685		55	31	− 3	6·0	7·7	Es.	
45	Schj. 88	7	1	37	− 7	23·3	8·3	Es.	
46	Schj. 89		2	55	−11	45·6	7·6	Se.	
47	+14°·1594		6	13	+14	53·5	9·0	Es.	
48	+48°·1504		9	57	+48	42·0	9·0	Es.	
49	+25°·1641		13	55	+25	11·6	9·0	Es.	
50	−3°·1886		19	24	− 4	0·9	8·7	Es.	
51	−2°·2101		19	47	− 2	54·5	9·0	Es.	
52	+24°·1686		25	14	+24	44·8	8·2	Es.	
53	+2°·1715		30	23	+ 2	19·0	9·3	Es.	
54	+5°·1797		42	55	+ 5	41·9	9·0	Es.	
55	−13°·2247		44	35	−13	49·2	7·2	K.	
56	Schj. 103		53	15	−49	41·2	8	Pe.	
57	Pickering 26		57	1	−12	46·6	var.	Pi.	
58	Schj. 115	8	49	11	+17	38·5	6·5	D'A.	
59	T Cancri		50	23	+20	16·2	var.	Es.	
60	+11°·1954		52	17	+11	15·5	var.	Es.	
61	Schj. 124	9	45	59	−22	30·2	7·3	Pe.	
62	Schj. 125		50	56	−41	3·9	7½	Pe.	
63	Schj. 126		56	23	−59	41·4	7¾	Pe.	
64	Schj. 128	10	7	4	−34	46·7	7½	Pe.	
65	Schj. 130		30	20	−38	59·6	5·9	Pi.	
66	U Hydræ		32	7	−12	48·8	var.	Se.	
67	+68°·617		37	25	+67	59·1	6·2	Du.	
68	Schj. 136		46	17	−20	40·0	6·8	Se.	
69	Schj. 145	12	19	37	+ 1	22·8	8·1	D'A.	
70	Schj. 152		39	57	+46	2·5	5·5	Se.	
71	Schj. 155*b*		52	6	+66	35·4	7·3	D'A.	
72	−2°·3638	13	4	3	− 2	47·9	8·3	K.	
73	V Coronæ	15	45	36	+39	54·2	var.	Du.	
74	V Ophiuchi	16	20	36	−12	10·6	var.	Du.	
75	Schj. 202	17	23	14	−19	23·0	7·8	Du.	
76	Schj. 205		38	29	−18	36·5	8·5	Du.	
77	+4°·3779	18	25	6	+ 4	18·6	9·5	Es.	
78	+36°·3168		28	32	+36	54·9	8·5	Du.	

No.	Schj., D.M., &c.	α 1890 h	m	s	δ °	′	Mag.	Auth.	Note.
79	$-7^{\circ}\cdot4633$	18	31	7	− 7	41·4	9·0	Es.	
80	$+36^{\circ}\cdot3243$		39	1	+36	51·3	7·5	Du.	
81	Schj. 219		43	57	− 8	1 8	7·1	Du.	
82	Schj. 221		51	56	+ 0	18·6	9·2	Es.	
83	Schj. 222		53	30	+14	12·9	9·0	Du.	
84	Schj. 222c		58	32	− 5	50·8	7·0	V.	
85	$-16^{\circ}\cdot5272$	19	12	51	−16	6·4	6·8	Es.	Holden 7
86	Schj. 229		25	28	+76	20·4	6·5	Se.	
87	$+45^{\circ}\cdot2906$		25	31	+45	49·1	8·6	Es.	
88	Schj. 228		28	1	−16	36·7	7·2	Se.	
89	$+32^{\circ}\cdot3522$		36	44	+32	22·8	8·0	Du.	
90	$+43^{\circ}\cdot3425$		53	40	+43	57·9	8·2	Du.	
91	$+27^{\circ}\cdot3612$	20	0	14	+20	20·2	7·8	Es.	
92	$+47^{\circ}\cdot3031$		6	7	+47	31·5	9·3	Du.	
93	$+35^{\circ}\cdot4002$		6	14	+35	37·6	9·5	Pi.	
94	Pickering 38		6	57	+35	47·1	var. (?)	Pi.	
95	$+38^{\circ}\cdot3957$		9	25	+38	23·8	8·7	Du.	
96	V Capricorni		10	40	−21	38·3	var.	Se.	Schj. 238
97	$+37^{\circ}\cdot3876$		14	28	+37	6·9	9·	Es.	
98	U Cygni		16	11	+47	32·8	var.	Du.	
99	$+36^{\circ}\cdot4028$		17	12	+36	33·2	9·5	Es.	
100	$+37^{\circ}\cdot3903$		17	24	+37	10·4	9·4	Es.	
101	$+39^{\circ}\cdot4208$		24	50	+39	36·7	9·2	Es.	
102	V Cygni		37	37	+47	44·9	var.	V.	
103	Es. 287		41	19	+44	27·7	8·5	Es.	
104	$+45^{\circ}\cdot3271$		43	7	+45	38·9	8·8	Es.	
105	Schj. 248b	21	18	16	+41	55·6	9·5	Du.	
106	S Cephei		36	35	+78	7·7	var.	Du.	
107	Schj. 249a		37	23	+35	0·5	6·2	D'A.	
108	Schj. 251		38	43	+37	30·8	7·8	Se.	
109	Schj. 257		51	8	+49	58·6	9·1	Du.	
110	$+54^{\circ}\cdot2865$	22	44	11	+54	31·7	8·5	Es.	
111	$+58^{\circ}\cdot2586$	23	18	56	+58	34·6	9·0	Es.	
112	19 Piscium		40	46	+ 2	52·6	var.	Se.	Schj.
113	$+42^{\circ}\cdot4824$		58	43	+42	59·6	8·6	Es.	

On a Method of Supporting a Large Mirror when Silvering. By Edward Crossley, M.P.

On account of the recent construction of large reflecting telescopes, and their application to celestial photography, it seems important to record the means by which any difficulties in handling large mirrors have been overcome. I therefore venture to lay before the Society a description of a method of supporting and handling a 3-foot mirror when silvering. It differs from Sir Howard Grubb's method of handling a large mirror principally in having a groove in the edge of the mirror.

Two plates have cylindrical ribs fitting into the groove, with pivots on the outside; the plates are held in their places on two opposite sides of the mirror by a copper band passing over and rivetted to them. The band is cut in two at two points 90° from the pivots; the cut ends are then united by screw bolts. This renders it an easy matter to get band and ribs into their places. A stirrup with holes for the pivots to slip into is then put on; and to facilitate this the stirrup is cut in two at the top and the two halves secured by a screw bolt.

The band, pivots, plates, and ribs are of copper; the ends of the stirrup of aluminium bronze. All these are coated with silver, to protect them from the action of the silvering solution.

In the annexed figure M is the mirror, S the stirrup, *p* the pivots, *g* the groove, B the band.

In this way the mirror can be lifted and placed at any angle with the greatest ease and with perfect safety.

The groove round the edge of the mirror is $\frac{3}{16}$ in. in depth, the plates $8\frac{1}{2}$ in. by 3 in. by $\frac{3}{16}$ in.; the band is $1\frac{1}{2}$ in. in width and $\frac{1}{16}$ in. thick, but where it is rivetted to the plates it is of the same width as the plates.

The readiness with which the mirror can be set at any angle obviates the necessity for using a large quantity of silvering solution; and by setting the mirror at an angle of 7° and the silvering vessel at half that inclination the quantity of solution can be reduced to less than six gallons, at least ten gallons being required to get out all the air when the vessel is horizontal.

1888.	Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Comps.	Comet's App. R.A.	Log (p×Δ).	Comet's App. Dec.	Log (p×Δ).	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Nov. 20	11 30 21	+1 19·67	+7 30·7	9–9	3 30 10·37	8·0309	−3 28 30·9	0·8609	+2·97	+ 7·6	29
22	10 51 0	−2 36·79	−9 46·5	8–8	3 16 21·86	$8·2445_n$	−4 5 39·3	0·8641	+2·97	+ 7·8	30
23	11 28 43	+3 26·32	−9 52·9	9–9	3 9 11·63	8·7781	−4 23 50·9	0·8655	+2·95	+ 8·2	31
26	12 39 9	−1 36·10	−3 55·9	7–7	2 48 10·46	9·3251	−5 13 47·0	0·8646	+2·92	+ 8·4	32
Dec. 5	7 59 18	+2 49·02	+5 27·1	8–8	1 53 5·92	$8·8880_n$	−6 54 57·4	0·8770	+2·68	+ 9·2	33
6	7 58 30	−1 39·57	+5 58·6	9–9	1 47 35·38	$8·8042_n$	−7 2 21·3	0·8778	+2·67	+ 9·0	34
7	8 6 25	−2 27·36	+6 28·9	8–8	1 42 13·19	$8·5608_n$	−7 9 4·3	0·8788	+2·64	+ 9·0	35
9	8 41 11	+2 36·81	+2 20·5	7–7	1 31 55·81	8·6829	−7 20 20·0	0·8795	+2·56	+ 9·3	36
13	7 25 1	−1 31·54	−2 26·6	8–8	1 13 53·89	$8·2955_n$	−7 35 0·0	0·8809	+2·46	+ 9·2	37
22	7 1 47	−4 23·44	+4 30·1	8–8	0 41 53·34	8·7067	−7 39 24·0	0·8808	+2·21	+ 9·2	38
23	9 6 18	+3 28·97	+5 37·9	1–1	0 38 45·67	9·3814	−7 38 2·5	0·8709	+2·14	+ 9·4	39
26	9 22 40	+1 23·00	+1 49·1	8–8	0 30 49·50	9·4490	−7 32 51·0	0·8659	+2·07	+ 9·4	40
30	6 51 46	−1 58·77	+3 51·8	8–8	0 21 58·40	9·0620	−7 23 11·8	0·8780	+1·99	+ 9·3	41
30	7 5 41	−4 11·21	+3 20·5	4–4	0 21 56·93	9·1346	−7 23 7·4	0·8772	+2·00	+ 9·2	42
31	7 11 37	−1 32·17	−7 10·7	8–8	0 19 54·02	9·1873	−7 20 29·3	0·8761	+1·97	+ 9·4	43
1889. Jan. 1	6 20 51	+1 6·46	−1 47·9	8–8	0 18 0·79	8·9335	−7 17 29·5	0·8784	−1·13	−10·6	44

November 20–22.—Very windy. Clock almost inaudible at times.

November 23.—Observation obtained with difficulty. Very high wind and passing clouds.

December 6.—Comet faint at times, owing to light cirrus clouds.

December 30. A small star was almost coincident with the nucleus of the comet at the commencement of the observations. December 31. Comet very faint, from haze.

	Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Comps.	Comet's App. R.A.	Log (p×Δ).	Comet's App. Dec.	Log (p×Δ).	Red. to App. Place.		Comp. Star.
1889.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Jan. 20	6 28 45	+1 14·64	+ 2 18·0	8–8	23 53 18·57	9·3751	−6 2 29·0	0·8657	−1·47	−10·8	45
27	6 46 8	−1 20·01	+ 0 53·1	8–8	23 48 20·42	9·4648	−5 30 31·9	0·8590	−1·53	−10·8	46
Feb. 4	6 55 47	+1 17·13	+10 30·2	2–2	23 44 18·84	9·5170	−4 52 48·4	0·8524	−1·62	−10·8	47
8	6 35 8	+1 8·43	− 2 41·8	5–6	23 42 48	9·5137	−4 33 57	0·8523	−1·64	−10·8	48
					Comet V., 1888 . . . (*Barnard's*, *October* 30, 1888.)						
1888.											
Nov. 13	17 28 55	−1 27·17	− 9 36·1	7–7	10 2 29·56	$8·9372_n$	−12 58 29·0	0·9008	+1·45	− 2·0	49
Dec. 6	15 53 56	+1 33·13	− 2 18·0	8–8	10 23 22·19	$9·0935_n$	− 7 16 22·2	0·8771	+2·11	− 8·1	50
7	15 47 7	−1 29·57	+ 6 36·6	8–8	10 23 55·03	$9·1109_n$	− 6 57 19·0	0·8756	+2·12	− 8·4	51
9	15 42 13	−2 8·49	+ 0 54·5	8–8	10 24 55·82	$9·1005_n$	− 6 18 15·1	0·8729	+2·18	− 9·1	52
12	15 49 7	+2 13·39	− 7 31·0	8–8	10 26 12·84	$8·9970_n$	− 5 16 25·7	0·8689	+2·29	−10·1	53
26	11 54 53	−1 7·41	+ 6 31·2	8–8	10 28 7·54	$9·5035_n$	+ 0 20 26·2	0·8406	+2·71	−14·9	54
30	12 2 45	−1 25·29	− 6 44·8	8–8	10 27 24·81	$9·4750_n$	+ 2 13 28·5	0·8335	+2·83	−16·3	55

February 8.—Comet faint, from moonlight. The wind being very high the clock was heard with difficulty.
November 13.—Comet fairly bright, but overpowered by twilight latterly.
December 6.—Comet rather faint. Sky hazy. December 26.—Comet faint and observation difficult.
December 30.—Comet faint and observation difficult, owing to the proximity of a small star.

1889		Greenwich Mean Time.	Comet—Star. Δα.	Comet—Star. Δδ.	No. of Comps.	Comet's App. R.A.	Log (p×Δ).	Comet's App. Dec	Log (ρ×Δ).	Red. to App. Place.		Comp. Star.
		h m s	m s	′ ″		h m s		° ′ ″		s	″	
Jan.	1	12 6 27	−1 21.17	+1 15.4	8–8	10 26 50.88	9.4584n	+ 3 13 3.5	0.8289	−0.20	+1.5	56
	3	11 21 51	+1 37.37	+5 30.4	8–8	10 26 9.22	9.5043n	+ 4 12 53.7	0.8281	−0.13	+0.8	57
	7	12 1 41	+4 41.65	−6 37.5	8–8	10 24 18.32	9.4254n	+ 6 19 9.3	0.8122	−0.01	−0.6	58
	27	10 14 6	+0 53.11	−4 48.4	8–8	10 8 0.67	9.4648n	+17 29 18.3	0.7456	+0.46	−5.0	59
	29	12 10 34	+1 43.47	−6 10.4	9–9	10 5 47.32	9.0776n	+18 38 17.6	0.6921	+0.50	−5.2	60
Feb.	2	9 20 17	−1 43.42	−9 21.7	3–3	10 1 29.44	9.5075n	+20 43 7.0	0.7331	+0.57	−5.5	61
	4	9 52 31	−1 59.55	+4 13.6	8–8	9 59 12.69	9.4441n	+21 46 27.6	0.7008	+0.61	−5.5	62
	20	9 48 15	+1 23.80	−3 45.7	9–9	9 41 27.16	9.2613n	+28 53 2.5	0.5694	+0.80	−4.3	63
Mar.	2	8 21 2	−1 53.02	−0 31.0	9–9	9 32 14.19	9.3996n	+32 5 11.2	0.5478	+0.83	−2.7	64
	3	8 16 43	−3 22.21	−3 57.8	8–8	9 31 26.65	9.3997n	+32 21 14.5	0.5432	+0.83	−2.5	65
	5	11 11 7	−1 41.63	+0 16.4	8–8	9 29 50.14	8.8949	+32 54 11.9	0.4643	+0.82	−2.1	66

January 1.—Comet fainter. January 7.—Comet faint and difficult to observe.

February 2.—Observation interrupted by clouds. February 20.—Observation not quite satisfactory.

March 3.—The comet appears to maintain its lustre in a remarkable manner and is not sensibly fainter than it was at the end of January.

Assumed Mean Places of Comparison Stars.

Comet III. 1888.

Comp. Star.	R.A. 1888·0. h m s	Decl. 1888·0. ° ′ ″	Authority.
1	12 56 5·87	+38 39 6·0	½ (2 Arm.₂ 1513 + Lal. 24246).
2	13 24 51·52	+35 6 10·2	⅓ (2 B.W.₂ 456 + Lal. 24993).
3	13 44 58·57	+33 4 39·9	½ (B.W.₂ 932 + Lal. 25499).
4	14 10 29·15	+29 8 55·0	B.W.₂ 184.
5	14 12 46·25	+28 13 39·7	Equat. comparison with B.W.₂ 151, B.W.₂ 182, and B.W.₂ 238.
6	14 22 8·13	+27 29 13·1	Equat. comparison with B.B. vi. + 27°·2375 B.W.₂ 566.
7	15 14 59·49	+17 39 7·7	Equat. comparison with B.B. vi. + 17°·2848 and B.W.₂ 242. (Decl. doubtful.)
8	15 20 25·19	+16 55 35·4	½ (B.W.₂ 400 + Lal. 28135).
9	15 28 44·74	+14 50 19·9	Equat. comparison with B.W.₁ 447.
10	15 33 1·44	+14 19 26·1	B.W.₁ 598.
11	15 48 22·56	+11 45 56·5	½ (B.W.₁ 896 + Schj. 5628).
12	15 51 11·92	+10 26 52·7	B.W.₁ 944.
13	15 53 43·21	+ 9 50 1·7	Equat. comparison with B.B. vi. + 9°·3121 and 3139.

Comet 1889.

Comp. Star.	R.A.	Decl.	Authority.
14	6 49 43·11	+10 32 55·9	Equat. comparison with B.W.₁ 1400 and B.W.₁ 1535. (There is no star in the place of Lal. 13302. Its R.A. appears to be that of B.W.₁ 1400, and its declination that of B.W.₁ 1423.)
15	6 48 59·20	+10 15 2·9	Equat. comparison with B.B. vi. + 10°·1335 and B.W.₁ 1414.
16	6 50 16·16	+10 6 3·6	B.B. vi. + 10°·1335.
17	6 41 8·40	+ 8 38 20·1	B.W.₁ 1193.
18	6 38 5·44	+ 8 31 44·1	Equat. comparison with B.W.₁ 1152 and B.W.₁ 1175.
19	6 38 16·94	+ 8 26 30·6	Equat. comparison with B.W.₁ 1175.
20	6 32 46·38	+ 8 4 8·7	Equat. comparison with B.B. vi. + 8°·1414 and 1417, and with B.W.₁ 823 and 841. (It has been assumed that the R.A. of B.B. vi. + 8°·1414 and 1417 is in each case one second too small.)
21	6 31 51·67	+ 7 49 26·9	½ (B.W.₁ 908 + Schj. 2291).
22	6 28 42·45	+ 7 39 31·3	14 *Monocerotis* ½ (Gr. 9 yr. 637 + Arm.₁ 1502).
23	6 18 43·97	+ 6 54 6·4	B.W.₁ 489.
24	6 21 13·80	+ 6 34 31·4	B.W.₁ 576.

Comp. Star.	R.A. 1888·0.	Decl. 1888·0.	Authority.
	h m s	° ′ ″	
25	6 15 25·25	+ 6 30 40·3	Equat. comparison with B.W.₁ 523.
26	5 33 34·31	+ 3 21 14·5	B.W.₁ 801.
27	4 38 56·90	+ 0 21 37·0	½ (Glasg. 1151 + Paris 5437). Proper motion, amounting to −0ˢ·013 in R.A. and −0″·07 in decl., is assumed provisionally by comparison with Lal. 8934 and B.W.₁ 808.
28	4 17 37·61	− 1 13 44·7	⅓ (Lam. 575 + B.W.₁ 324 + Lal. 8262).
29	3 28 47·73	− 3 36 9·2	⅙ (2 Glasg. 833 + 2 Paris 4227 + B.W.₁ 491 + Lal. 6608).
30	3 18 55·68	− 3 56 0·6	⅓ (2 Glasg. 791 + B.W.₁ 300).
31	3 5 42·36	− 4 14 6·3	⅕ (Glasg. 739 + Arm.₂ 405 + Paris 3826 + Arg. Gen. Cat. 3442 + B.W.₁ 50).
32	2 49 43·64	− 5 9 59·5	Berlin Mer. Obs. AN. 2887.
33	1 50 14·22	− 7 0 33·6	Equat. comparison with B.W.₁ 851 and B.W.₁ 925.
34	1 49 12·28	− 7 8 28·9	B.W.₁ 851.
35	1 44 37·90	− 7 15 42·2	⅓ (Arm.₂ 239 + Paris 2286 + Arg. Gen. Cat. 1783). Proper motion, amounting to +0ˢ·014 in R.A. and +0″·08 in decl., is assumed provisionally by comparison with Lal. 3379 and B.W.₁ 765.
36	1 29 16·44	− 7 22 49·7	Equat. comparison with B.W.₁ 517 and B.W.₁ 536.
37	1 15 22·97	− 7 32 42·6	B.W.₁ 212.
38	0 46 14·57	− 7 44 3·4	½ (Lam. 51 + Equat. comparison with B.W.₁ 822).
39	0 35 14·57	− 7 43 49·8	½ (B.W.₁ 576 + Lal. 1076–7).
40	0 29 24·43	− 7 34 49·6	⅓ (B.W.₁ 471 + Lam. 35 + Schj. 196).
41	0 23 55·17	− 7 27 12·9	B.W.₁ 367.
42	0 26 6·14	− 7 26 37·1	B.W.₁ 400.
43	0 21 24·22	− 7 13 28·0	B.W.₁ 326.
	1889·0.	1889·0.	
44	0 16 55·46	− 7 15 31·0	Equat. comparison with B.W.₁ 265 and B.W.₁ 326.
45	23 52 5·39	− 6 4 36·3	½ (B.W.₁ 1029 + Lal. 46960).
46	23 49 41·97	− 5 31 14·2	½ (B.W.₁ 978 + Lal. 46879).
47	23 43 3·33	− 5 3 7·8	⅓ (2 Yarn. 10499 + B.W.₁ 848).
48	23 41 41	− 4 31 5	S.D.

Comet V. 1888.

	1888·0.	1888·0.	
49	10 3 55·28	−12 48 51·0	½ (Lal. 19796 + Lam. 653) and ½ (Lal. 19796 + B.W.₁ 9). The decl. of Lam. 653 is 14″·4 less, and the R.A. of B.W.₁ 9 is erroneous, being that of Lal. 19786, a star which precedes 21 seconds.

Comp. Star.	R.A. 1888·0.	Decl. 1888·0.	Authority.
	h m s	° ′ ″	
50	10 21 46·95	− 7 13 56·1	$\frac{1}{3}$ (B.W.,1 351 + Lam. 888 + Lal. 20283).
51	10 25 22·48	− 7 3 47·1	$\frac{1}{4}$ (Gr. 7 yr. 1280 + Yarn. 4377 + Glasg. 2742 + Arm.,1 2286).
52	10 27 2·13	− 6 19 0·4	$\frac{1}{2}$ (Schj. 3861 + Equat. comparison with B.W.,1 414 and B.W.,1 524).
53	10 23 57·16	− 5 8 44·7	Lam. 899.
54	10 29 12·24	+ 0 14 9·9	Lam. 2989.
55	10 28 47·27	+ 2 20 29·6	$\frac{1}{4}$ (Glasg. 2751 + B.W.,1 473 + Lal. 20472 + Lam. 2988), using Grant's P.M.
	1889·0.	1889·0.	
56	10 28 12·25	+ 3 11 46·6	$\frac{1}{4}$ (B.W.,1 462 + Schj. 3865 + Lam. 273 + Lal. 20456).
57	10 24 31·98	+ 4 7 22·5	$\frac{1}{2}$ (B.W.,1 401 + Lam. 249).
58	10 19 36·69	+ 6 25 47·5	$\frac{1}{3}$ (B.W.,1 301 + Lam. 220 + Lal. 20196).
59	10 7 7·10	+ 17 34 11·7	$\frac{1}{2}$ B.W.,2 108–9 + Equat. comparison with Lal. 19906).
60	10 4 3·35	+ 18 44 33·3	$\frac{1}{2}$ (B.W.,2 15–16 + B.B. vi. + 18°·2326).
61	10 3 12·29	+ 20 52 34·2	$\frac{1}{3}$ (2 Yarn. 4224 + B.W.,2 1316–7).
62	10 1 11·63	+ 21 42 19·5	B.B. vi. + 21°·2153.
63	9 40 2·56	+ 28 56 52·5	Equat. comparison with B.B. vi. + 29°·1948.
64	9 34 6·38	+ 32 5 44·8	Equat. comparison with B.B. vi. + 32°·1913 and 1917.
65	9 34 48·03	+ 32 25 14·8	B.B. vi. + 32°·1915.
66	9 31 30·96	+ 32 53 57·6	B.W.,2 620.

Col. Tomline's Observatory, Orwell Park:
1889, *March* 18.

Errata in Professor Oudemans' Paper, Vol. xlix. No. 2.

Page 54, 4th line from bottom (of text), *for* instrumental arc *read* instrumental axes.
Page 56, 7th line from bottom (of notes), *for* more than one figure *read* one figure more.
Page 59, 3rd line from bottom, *for* directions *read* direction.
Page 61, 7th line from bottom (of text), *for* limit of the moments *read* limit of the proportion between the moments.
Page 61, 2nd line from bottom (of note), *for* Beobactungen *read* Beobachtungen.

Errata in Dr. Gill's Paper, Vol. xlix. No. 3.

Page 107, 13th line from top, *for* E *read* ε.
Page 109, 2nd line from bottom (of note), *for* reckoning *read* revolution.
„ „ „ „ *for* round number 10′ *read* round number 10″.
Page 112, 2nd line from top, *for* rapidly *read* rigidly.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. MAY 10, 1889. No. 7

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Edward Carpmael, B.A., The Ivies, St. Julian's Farm Road, West Norwood, S.E.;
James George Petrie, 15 Mercer's Road, Holloway, N.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

Richard Evan Day, M.A., Lecturer on Nautical Astronomy at the Birkbeck Institute, 48 Belsize Square, N.W. (proposed by the Rev. A. L. Watherston);
Philip F. Duke, Journalist, Hendon, Middlesex (proposed by the Rev. S. J. Perry);
The Rev. Thomas Jones, B.A., LL.D., Rector of Curdworth, Warwickshire (proposed by Professor J. C. Adams);
James Oddie, J.P., F.G.S., F.R.G.S., School of Mines, Ballarat, Victoria (proposed by A. Cowper Ranyard).

The following were proposed by the Council as Foreign Associates:—

S. C. Chandler, Cambridge, Mass., U.S.A.;
N. C. Dunér, Observatory, Lund, Sweden;
Paul Henry, Observatory, Paris;
Prosper Henry, Observatory, Paris.

Mean Areas and Heliographic Latitudes of Sun-spots, 1874 to 1888, deduced from Photographs taken at Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The following tables give the results of the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius, for each synodic rotation of the Sun in 1888, and for each year from the commencement of the Greenwich series. The Indian series of Sun pictures used in these measurements begins on 1881 December 22, and the Mauritius series on 1885 January 3. The daily photographic record is practically complete from the beginning of 1882.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1888. The areas are given in two forms: first, projected areas—that is, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disk; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere. Table II. gives the mean daily areas (corrected for foreshortening) for each year from the commencement of the Greenwich series, and the projected areas for the years 1882 to 1888, the projected areas for the years preceding 1882 not having yet been computed. Table III. exhibits for each rotation in 1888 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots. Table IV. gives the same information for each year from 1874 to 1888.

Table I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of days on which Photographs were taken.	Mean of Daily Areas. Projected.			Corrected for Foreshortening.		
			Umbræ.	Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
458	1887 December 26·77	26	33	202	366	24	145	462
459	1888 January 23·11	27	3	14	205	3	15	255
460	February 19·45	26	37	243	219	24	157	262
461	March 17·77	27	5	37	279	5	34	299
462	April 14·06	26	5	29	190	4	26	223
463	May 11·30	28	50	276	203	37	206	226
464	June 7·51	27	7	58	305	5	36	326
465	July 4·71	27	4	30	177	3	25	214
466	July 31·91	27	4	28	130	3	20	158
467	August 28·15	28	31	208	235	23	152	279
468	September 24·42	27	2	19	120	1	8	143
469	October 21·71	27	51	304	120	34	205	135
470	November 18·01	26	36	204	216	24	143	234

The rotations in the above table are numbered in continuation of Carrington's series (Observations of Solar Spots made at Redhill by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich Civil Time, reckoning from mean midnight.

TABLE II.

Year.	No. of days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Projected. Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
1873	58	...	...	...	120	701	3401
1874	159	...	...	...	85	601	813
1875	161	...	...	...	48	272	451
1876	162	...	...	...	25	122	256
1877	168	...	...	...	19	92	175
1878	146	...	...	...	5	24	90
1879	126	...	...	...	11	49	151
1880	158	...	...	...	85	416	977
1881	181	...	...	...	149	730	1733
1882	343	254	1339	2033	189	1002	2154
1883	340	283	1556	1592	175	1155	1856
1884	315	172	1304	1501	148	1079	2057
1885	354	146	1136	1250	101	811	1496
1886	363	71	527	473	50	381	579
1887	361	37	243	256	26	179	301
1888	358	20	126	204	14	89	236

The Means of Daily Areas for the year 1873 refer to a period of about five months commencing 1873 July 28.

Many of the photographs taken during the early part of 1874 do not show the faculæ with sufficient distinctness to allow of their measurement. The mean of daily areas of faculæ for the half-year beginning 1874 June 20 is 1102.

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of entire Spotted Area.	Mean Distance from Equator of all Spots.
				°		°	°	°
458	1887 December 26·77	26	11	+ 2·65	134	−8·50	−7·65	8·06
459	1888 January 23·11	27	0	...	15	−5·10	−5·10	5·10
460	February 19·45	26	66	+ 2·99	91	−4·66	−1·46	3·96
461	March 17·77	27	23	+ 3·18	11	−8·61	−0·61	4·93
462	April 14·06	26	0	...	26	−7·48	−7·48	7·48
463	May 11·30	28	0	...	206	−8·01	−8·01	8·01
464	June 7·51	27	15	+ 4·75	22	−6·15	−1·74	5·59
465	July 4·71	27	2	+ 5·95	24	−9·80	−8·65	9·52
466	July 31·91	27	4	+ 7·48	16	−4·07	−1·99	4·68
467	August 28·15	28	2	+ 5·03	150	−7·25	−7·10	7·22
468	September 24·42	27	0	+ 1·95	8	−5·62	−5·58	5·60
469	October 21·71	27	141	+ 10·20	65	−4·07	+ 5·71	8·27
470	November 18·01	26	0	...	143	−9·98	−9·98	9·98

TABLE IV.

Year.	No. of days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1874	132	275	+ 9·01	362	−12·18	−3·03	10·81
1875	161	153	+ 11·16	119	− 9·46	+ 1·99	10·58
1876	162	32	+ 12·58	90	−10·91	−4·66	11·35
1877	168	26	+ 9·12	65	− 9·51	−4·18	9·40
1878	146	24	+ 7·14	1	− 8·09	+ 6·92	7·15
1879	126	14	+ 23·59	35	−22·51	−9·18	22·82
1880	158	257	+ 20·01	159	−19·45	+ 4·90	19·80
1881	181	500	+ 18·17	229	−18·29	+ 6·70	18·21
1882	343	443	+ 15·99	558	−19·26	−3·67	17·81
1883	340	340	+ 10·99	815	−13·90	−6·57	13·04
1884	315	478	+ 10·67	601	−11·74	−1·82	11·27
1885	354	283	+ 10·54	528	−12·41	−4·40	11·76
1886	363	76	+ 9·93	305	−10·50	−6·42	10·38
1887	361	44	+ 8·75	134	− 8·34	−4·09	8·44
1888	358	20	+ 7·10	69	− 7·48	−4·22	7·39

The Means of Daily Areas, &c., in Table IV. for the year 1874, refer to a period of eight months from 1874 April 27, to 1874 December 28.

The foregoing tables would appear to indicate that the Sun-spot minimum is now close at hand; for the mean daily area of Sun-spots for the year 1888 was slightly smaller than for the year 1877, and the period of complete quiet at the last minimum commenced in November 1878, so that supposing the present decline to follow precisely the precedent of the last, the minimum would take place before the close of the present year. The distribution of the spots in latitude points to a similar conclusion, for the mean distance from the equator of all spots for 1888 is almost as small as for the year 1878. A further indication in the same direction has already been pointed out by the Rev. S. J. Perry (*Nature*, vol. xxxix. p. 223). In previous cycles it has often occurred, as Professor Spoerer has pointed out, that, whilst during the decline to minimum the mean distance from the equator of all spots has steadily decreased, the fact that the minimum has been passed has been signalised by the appearance of a spot in a high latitude. On 1888 December 30, a small faint spot was observed in 36° S. latitude. It was, indeed, a very small and evanescent spot; it had not formed at $5^h\ 51^m$ Greenwich Civil Time, when the daily photograph of the Sun was taken at Dehra Dûn; but it was fairly conspicuous at $10^h\ 35^m$ G.C.T., when it was seen and drawn at Stonyhurst College Observatory. It was still visible though very small and faint at $13^h\ 5^m$ G.C.T., when a photograph was taken at the Royal Observatory, Greenwich, but it had wholly disappeared before the next day.

Table IV. brings out the remarkable predominance as to spotted area which the southern hemisphere has shown over the northern during the last seven years. From 1874 to 1881, sometimes the one hemisphere and sometimes the other appeared the more prolific, but on the whole the spots were very evenly divided between the two. In 1881 the mean spotted area north was more than double the mean area south, but in April 1882 there was a very remarkable outburst in the southern hemisphere which transferred the predominance to that region. In November of the same year the largest single spot of the present cycle appeared in the northern hemisphere, and the balance was again shifted, but after its disappearance the southern hemisphere has been almost invariably the richer of the two; indeed, for the total of the last six years the area south has been very nearly double that of the area north, and whilst many rotations have been entirely barren of spots north of the equator, that has never been the case south. Corresponding to this inferiority in extent of spotted area for the northern hemisphere has been a similar inferiority in mean latitude; the mean latitude of the southern spots being considerably greater than of the northern for each year from 1882 to 1888, with the single exception of 1887.

Royal Observatory, Greenwich:
1889 *May* 9.

Note on an Error in Le Verrier's "Tables du Soleil."
By R. T. A. Innes.

There is a small error in Le Verrier's Tables of the Sun (*Les Annales*, vol. iv.) which, as far as I am aware, seems to have escaped detection.

In the expression for R on p. 103 the same variation of the excentricity is used as on p. 54, viz.:—

$$-0{\cdot}000{,}000{,}4338$$

instead of

$$-0{\cdot}000{,}000{,}4244$$

resulting from $-0''{\cdot}08755$ on p. 102.

In calculating R especially for a distant epoch it will be worth while to take this correction into account.

In vol. xl. p. 598 of the *Monthly Notices*, Sir G. B. Airy puts

$$\frac{\text{Variation of E for 1 year}}{\text{E}} = -\frac{{\cdot}0000004338}{{\cdot}01676927};$$

this should be

$$-\frac{{\cdot}0000004244}{{\cdot}01677106}.$$

This changes the value of the lunar acceleration from

$$5''{\cdot}4773 \text{ to } 5''{\cdot}3587.$$

The two following tables will enable the correction to be applied during the time covered by Le Verrier's Tables.

Le Verrier's Tables of the Sun. Section V. Table XXXII.

The seventh decimal place taken for unity.

Mean Anomaly.		Correction to Var. Séc. Natl. No.	Correction to Var. Séc. Logar n.	Mean Anomaly.	
0	360	−9·3 +	−4·0 +	180	180
5	355	−9·3 +	−4·0 +	175	185
10	350	−9·2 +	−4·0 +	170	190
15	345	−9·0 +	−3·9 +	165	195
20	340	−8·7 +	−3·8 +	160	200
25	335	−8·4 +	−3·7 +	155	205
30	330	−8·1 +	−3·5 +	150	210
35	325	−7·6 +	−3·3 +	145	215
40	320	−7·1 +	−3·1 +	140	220
45	315	−6·6 +	−2·9 +	135	225
50	310	−6·0 +	−2·6 +	130	230

Mean Anomaly.		Correction to Var. Séc. Natl. No.	Logarm.	Mean Anomaly.	
55	305	−5·3+	−2·3+	125	235
60	300	−4·6+	−2·0+	120	240
65	295	−3·9+	−1·7+	115	245
70	290	−3·2+	−1·4+	110	250
75	285	−2·4+	−1·1+	105	255
80	280	−1·6+	−0·7+	100	260
85	275	−0·8+	−0·3+	95	265
90	270	−0·0+	−0·0+	90	270

Section VI. Table II.

Correction to R.

Sun's Longitude.		1860.	1870.	1880.	1890.	1900.	Sun's Longitude.	
280	280	−0·9+	−1·9+	−2·8+	−3·7+	−4·6+	100	100
290	270	−0·9+	−1·8+	−2·8+	−3·7+	−4·6+	90	110
300	260	−0·9+	−1·7+	−2·6+	−3·5+	−4·3+	80	120
310	250	−0·8+	−1·6+	−2·4+	−3·2+	−4·0+	70	130
320	240	−0·7+	−1·4+	−2·3+	−2·8+	−3·5+	60	140
330	230	−0·6+	−1·2+	−2·0+	−2·4+	−3·0+	50	150
340	220	−0·5+	−0·9+	−1·6+	−1·8+	−2·3+	40	160
350	210	−0·3+	−0·6+	−1·2+	−1·3+	−1·6+	30	170
360	200	−0·2+	−0·3+	−0·5+	−0·6+	−0·8+	20	180
10	190	−0·0	−0·0+	−0·0+	−0·0+	−0·0+	10	190

Extract from a letter from Professor J. C. Adams to Mr. Knobel.

'Mr. Innes is quite right in pointing out that the variation of the excentricity in the expression of the radius vector does not agree with that given in the definitive value adopted for the equation of the centre. It really agrees with the value of the variation of the excentricity given in page 53, which is that which is consistent with the masses of the planets which are assumed in page 49. The correction of the annual variation of the excentricity is given in page 55, in terms of the corrections of the planetary masses. The values of $2\delta e$ which result from the observations, chiefly those of Greenwich, are given on page 89, and these indicate a smaller value of the variation of the excentricity than that employed in the original theory.'

Parallel Photographs of the Spectra of the Sun, of Iron, and of Iridium, from the Line (H) *to near the Line* (D), *in six sections. Also separate Photographs of the Spectrum of Titanic Iron Ore, in six sections.* By Frank M'Clean, M.A.

The photographs of the solar and metallic spectra now brought before the Society follow the same scheme as the "Photographs of the red end of the Solar Spectrum," presented by the writer in December 1888.

The division into sections and the scale (approximately) are the same as in Ångström's Normal Solar Spectrum. This plan has the advantage of always presenting the spectra in the same familiar divisions, and also of rendering these divisions suitable for direct comparison with Ångstrom's chart.

The present photographs comprise, in the first place, the first six sections of the solar spectrum numbered I. to VI. Taken along with the seven sections comprised in the "red end of the solar spectrum" previously given, and numbered 7 to 13, they complete the whole visible solar spectrum, from (H) to (A).

The present six sections of the solar spectrum are accompanied by corresponding and parallel photographs of the spectra of metallic iron, and of metallic iridium.

The iridium spectrum was fixed upon in order to obtain a full spark spectrum of air, for purposes of comparison. It shows Kirchhoff's iridium lines at wave-lengths 5299 and 5450. It also shows other unregistered lines, either of iridium or of air, which however can only be identified correctly when photographs of further spectra have been obtained. The air lines are present, more or less distinctly, in all spark spectra taken in air, and they supply a ready and accurate means of co-ordinating such spectra with the iron spectrum and with each other.

The iron spectrum was fixed upon on account of its close correspondence throughout with the spectrum of the Sun, and its thus furnishing the best means of co-ordinating the spectra of the other metals with the solar spectrum. The reference of the metallic spectra to the scale of wave-lengths established by Ångström's Normal Solar Spectrum is thus obtained, and it should be borne in mind that Ångström's spectrum is the only complete spectrum of any kind which has been determined to the scale of wave-lengths by direct observation.

It should be remembered that the photographs are only suitable for filling in the details of the spectra between the standard reference lines. Neither the spectroscope used nor the photographic impression is suitable for the accurate measurement of the angle of divergence between the standard lines themselves. A much more compact spectroscope with graduations and adjustments of the most perfect character would be absolutely necessary for such a purpose. The radical difference between measure-

ments within the field of view and independent measurements of direction is involved. The want of rigidity scarcely avoidable with the long tubes of a spectroscope suitable for photography, although comparatively immaterial in the first case, would be fatal where the observation must be made along the line of collimation of the telescope and the direction accurately determined.

Thalén's determinations of the wave-lengths of the metallic spectra, which accompany Ångström's chart, were not made with a diffraction spectroscope. They were, in fact, Kirchhoff's and Hofmann's determinations of the metallic spectra, and were made with a refraction spectroscope to "Kirchhoff's scale." Thalén transformed them to wave-lengths by means of interpolation, on a curve drawn through a large number of points, whose abscissæ represented the wave-lengths of the lines of Ångström's solar spectrum.

Dr. Huggins' determinations of the "Spectra of the Chemical Elements" were also made with a refraction spectroscope. He proceeded by referring the observed spectrum to the lines of the air spectrum as lines of reference. The measurements were taken to the graduated scale of his own instrument. He determined the position of the principal lines of the solar spectrum to the same scale, but, being foreign to his purpose, he did not establish any more detailed connection between the spectra of the chemical elements and the solar spectrum. There seems, therefore, to be an opportunity for the co-ordination of the metallic spectra, by means of the direct comparison of photographs taken with the diffraction spectroscope, with Ångström's standard wave-length chart of the solar spectrum. The writer purposes, if possible, to continue the present series of photographs of the metallic spectra with this object in view.

The striking coincidence of the spectrum of iron with the solar spectrum is of course well known. But to many it is only hearsay knowledge. The present photographs display it to the eye itself, and they carry with them a conviction due to their being the self-recorded images of the phenomena themselves. Attention may be directed to Section V. as particularly rich in coincidences, including the double (E) line with components under one tenth-metre apart. The curious double character of nearly all lines at the violet end of the spectrum is shown in Sections I. and II., although on reaching (H) the definition of the spectroscope somewhat fails.

The same six sections of photographs of the spectrum taken between electrodes of iron and ilmenite (or titanic iron ore), mounted on loose slips, accompany the bound photographs, in order to illustrate the way in which the photographs can be compared with each other, and with Ångström's chart. If Section IV. of these slips be compared with Ångström's, the presence in the titanic iron ore, of titanium, chromium, cobalt, and calcium, is at once apparent. Magnesium and barium are also

shown by other sections. The same specimen of ore has unfortunately not been used for all the sections.

It is hoped eventually to extend the metallic spectra to three further sections, thus including the Fraunhofer line (C). But as this must be a much more laborious undertaking it has been for the present postponed.

As before, the photographs have been taken with a Rutherford grating ruled 17,296 lines to the inch, and about $1\frac{3}{4}$ inch square, and they have been enlarged from the original negative about $8\frac{1}{2}$ times.

The writer is unaware of any photographs of the metallic spectra, below the (H) group of lines in the violet, having hitherto been produced to the large scale of the present photographs.

The photographs which accompany the Paper have been placed in the Library.

Note on Terby's White Spot on the Ring of Saturn.
By A. A. Common, F.R.S.

On March 6, at 9.12 P.M., Dr. Terby at Louvain, using his 8-inch telescope, saw what he announced as a white spot on the ring of *Saturn* near the shadow of the planet. Subsequent observations confirmed this appearance to him, and since his observations were announced other observers in different parts of the world have been able to see a white spot on the rings.

On March 6 the 5-foot reflector at Ealing was in use on *Saturn* for several hours, including the time at which Dr. Terby first saw this white spot. Details of the markings on the planet and rings were noted, special attention was paid to the shadow (of the planet), which was seen to be irregular in outline, but nothing in the nature of a bright spot near it was noticed. The positions of the satellites were noted at 9 o'clock, and at 9.30 it was noted that *Mimas* was visible, although not clear of the ring in either case. The first information received at Ealing of Terby's white spot was a telegram from Aberdeen on March 14. "Terby announces région blanche sur anneau *Saturne*, contre ombre globe." Next day *Saturn* was observed with the 5-foot; the white spot was specially looked for, the ring was carefully examined all over, but nothing unusual could be made out. *Saturn* has been observed on ten other evenings since then by Mr. Taylor and by myself, but in no case has any definite white spot been seen.

The ring near the shadow always appears slightly brighter by contrast than the other portions of the ring do; and this effect is found to be much more marked with the 6-inch refractor than with the 5-foot reflector. A dark wedge has been used on many occasions since March. 14 by Mr. Taylor and myself on the 6-inch telescope and on the 5-foot, and in every case we have

found that the ring disappears at the same time all round, whereas if the white spot had any real existence (*i.e.* if it were really brighter than the other parts of the ring), it would have remained visible after the other portions of the ring had been cut out by the dark wedge. The appearance of increase of brightness can be produced with either the 6-inch refractor or the 5-foot reflector, on any part of the planet, at any time, by allowing it to pass partly out of the field when all parts of the ball and ring in immediate contact with the edge appear sensibly brighter than the rest of the planet. At the Lick Observatory, with an occulting bar on the 36-inch refractor, a similar effect was noticed at the edges of the bar.

The contrast appearance which is seen near the shadow of the planet on the ring is sometimes more obvious than at others, but atmospheric irregularities will explain much of this suspected variability. It is remarkable that such careful observers as Bond and others who have worked on *Saturn* should not have called attention to this appearance before, but it will probably be found much more prominent in certain positions of the planet and rings than in others.

The powers used have varied considerably; 300 has been generally used on the 6-inch, and as much as 1400 on the 5-foot. With the latter power the shadow has a decidedly notched appearance, the outer and brighter part of the middle ring (B) projecting farther into the shadow than any other part of the ring, although the outer ring (A) is closer to the planet than one would expect from the outline of the shadow on the inner portions of the ring. It may be that this notched appearance, which is only distinctly visible with very high powers, may have some connection with the appearance to which Dr. Terby directed attention, but the observations made at Ealing very decidedly point to the explanation of the supposed white region as an effect of contrast.

Saturn was photographed several times with the 5-foot in April. Although definition in the photographs is not good, the shadow can easily be made out by the absence of silver particles, but there are not the slightest indications of any bright spot on the rings near the shadow.

Photograph of the Nebula M 51 *Canum Venaticorum.* By Isaac Roberts.

The photograph which is now presented is an enlargement to ten times the negative of M 51 *Canum Venaticorum*, R.A. $13^{h}\ 25^{m}$, D. $+47^{\circ}\ 45'$. The negative was taken on April 28, 1889, with an exposure of four hours, and it adds considerably to our knowledge of the structure and the surroundings in space of this

nebula, and I think that it will be generally accepted as a demonstration of the truth of the nebular or of the meteoric hypothesis.

The nebula is well known by the numerous drawings and descriptions of it, particularly those by Herschel, Rosse, and Lassell.

The drawing by Lassell * agrees well in general outline with the photograph, and I must bear testimony to the fact that Lassell's drawings of other nebulæ also generally agree more closely with the photographs than do those of any other delineator that have come under my notice. But all drawings alike fail to present to the eye proportions, details, and outlines as they are shown on the photographs.

Referring now to the photograph before us, we see much more than the spiral form of a nebula with apparently two distant nuclei, for we see that the spirals have broken up at relatively short intervals into stars which are either coincident with, or very closely follow, all the convolutions of the spiral. The coincidence of the stars with the trend of the spiral from the nucleus to the farthest whorls of the nebulous stream is remarkable, and the condensation of the nebulous, or shall we say agglomeration of the meteoric matter into stars, is so striking that we feel deeply impressed by the singularity of the appearance, which to me is inexplicable by any hypothesis of fortuitous coincidence. If the evidence of condensation into stars rested alone upon that shown in this photograph it would be almost irresistible, but when we turn to re-examine and compare the photographs of M 81 *Ursæ Majoris* and M 31 *Andromedæ*, which have been presented to the Society, we find corroborative evidence that amounts, I submit, to a demonstration that we now see in various stages of progress the evolution of stellar systems corresponding with our ideas of the early state of the solar system.

The photograph is placed in the Library.

* *Mem. R.A.S.*, vol. xxxvi. pl. 6, fig. 27.

Observations of the Planet Iris and Comparison Stars, made with the Transit Circle of the Radcliffe Observatory, Oxford, during the Opposition of 1888.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

Observations of the Planet Iris.

[The N.P.D.'s are corrected for Refraction but not for Parallax.]

Greenwich Mean Time of Observation.		Observer.	Apparent Places. R.A.	Apparent Places. N.P.D.	Observer's Remarks.
1888.	h m s		h m s	° ′ ″	
Oct. 15	12 54 13	R.	2 29 5·35	66 15 17·78	
17	12 45 3	R.	2 27 46·22	66 25 19·46	Faint at times; cloudy.
19	12 35 47	R.	2 26 22·16	66 36 23·76	Very diffused.
20	12 31 8	F. B.	2 25 38·46	66 42 19·07	Bad image.
22	12 21 46	R.	2 24 8·30	66 54 57·88	Diffused and unsteady; foggy.
23	12 17 4	F. B.	2 23 22·06	67 1 38·88	Diffused and faint; foggy.
30	11 43 58	F. B.	2 17 46·35	67 54 31·03	Magnitude 7–6.
Nov. 13	10 38 44	F. B.	2 7 33·21	69 59 4·47	Magnitude 7 or 7–6.
16	10 25 16	F. B.	2 5 53·22	70 26 6·87	Magnitude 7 or 7–8. Diffused.
17	10 20 50	R.	2 5 23·28	70 34 59·66	Very faint; doubtful observation in N.P.D. Cloudy.
21	10 3 26	R.	2 3 42·12	71 9 28·81	
22	9 59 9	F. B.	2 3 21·61	71 17 48·35	Magnitude 7 or 7–8.
26	9 42 25	R.	2 2 20·48	71 49 29·81	Magnitude 7–8.
27	9 38 19	F. B.	2 2 10·56	71 56 59·07	Magnitude 7–8.
30	9 26 14	R.	2 1 53·42	72 18 21·92	Very faint; observation of little value; cloudy.
Dec. 1	9 22 17	F. B.	2 1 52·35	72 25 3·66	About ½ Mag. fainter than Arg. Z. + 17°, 315.
6	9 3 6	F. B.	2 2 20·39	72 55 16·15	Very faint; thick haze.
12	8 41 17	R.	2 4 7·19	73 23 52·92	

Observations of the Comparison Stars Observed with Iris.

Separate Results.

Day.	Observer.	Obs. Mag.	Mean R.A. 1888 Jan. 1.	Mean N.P.D. 1888 Jan. 1.	Notes.
			Arg. Z. + 17°, 307.		
1888.			h m s	° ′ ″	
Nov. 16	F. B.	6	1 57 34·03	72 17 7·27	Red star.
22	F. B.	6	34·00	7·70	Reddish.
27	F. B.	6	33·95	5·97	
		6	1 57 33·98	72 17 6·98	
			Arg. Z. + 17°, 315.		
Nov. 30	R.		2 1 36·95	72 30 15·45	
Dec. 1	F. B.		...	15·12	
22	F. B.	8	37·02	15·42	
		8	2 1 36·99	72 30 15·33	
			Arg. Z. + 16°, 247.		
Dec. 6	F. B.		...	73 18 2·66	
12	R.		2 3 14·07	3·60	
18	R.		14·02	4·03	
26	F. B.	7–6	13·83	4·85	
		7–6	2 3 13·97	73 18 3·79	
			Arg. Z. + 19°, 329.		
Nov. 16	F. B.	7½	...	70 10 57·08	Double; 7½ and 9½ or 10–9 Magnitudes.
17	R.		...	57·99	
1889. Jan. 1	R.		2 3 29·95	...	
		7–8	2 3 29·95	70 10 57·54	
			Arg. Z. + 18°, 277.		
1888. Nov. 21	R.		2 4 25·14	71 1 42·39	
22	F. B.	6–7	25·01	42·83	
		6–7	2 4 25·08	71 1 42·61	
			Arg. Z. + 20°, 341.		
Nov. 13	F. B.		2 5 6·07	69 9 1·59	

Day.	Observer.	Obs. Mag.	Mean R.A. 1888 Jan. 1.	Mean N.P.D. 1888 Jan. 1.	Notes.
			Arg. Z. + 21°, 298.		
1889.			h m s	° ′ ″	
Jan. 1	R.		2 6 2·98	68 32 33·73	
			Arg. Z. + 20°, 348 (*η Arietis*).		
1888.					
Nov. 27	F. B.	6–5	2 6 31·92	69 18 54·83	
Dec. 6	F. B.		31·90	54·44	
28	R.		31·84	56·11	
		6–5	2 6 31·89	69 18 55·13	
			Arg. Z. + 21°, 317.		
Dec. 12	R.		2 11 26·14	67 51 25·61	Estimation of Mag. Dec. 22 = 9–8.
18	R.		26·20	26·93	
		9 8	2 11 26·17	67 51 26·27	
			Arg. Z. + 19°, 340 (*θ Arietis*).		
Oct. 23	F. B.		2 11 53·70	70 37 1·77	
Nov. 13	F. B.	5–6	53·74	2·92	
20	F. B.	5½	53·78	1·26	
22	F. B.	5½	53·92	2·43	3 wires only in R.A. "Good."
Dec. 6	F. B.		53·77	1·59	
7	R.		53·74	2·52	
		5–6	2 11 53·77	70 37 2·08	
			Arg. Z. + 21°, 321.		
Dec. 22	F. B.	8	2 12 16·77	68 37 10·03	A star follows (Arg. Z. + 21, 322) 9 or 9–8 Mag.
26	F. B.	8–7	16·83	10·10	
		8	2 12 16·80	68 37 10·07	
			Arg. Z. + 22°, 329.		
1889.					
Jan. 1	R.		2 12 38·61	67 20 57·78	
			Arg. Z. + 19°, 346.		
1888.					
Nov. 16	F. B.	9	2 14 17·95	70 23 25·28	Very faint.
27	F. B.	9	17·97	23·11	Very faint.
		9	2 14 17·96	70 23 24·20	

Day.	Observer.	Obs. Mag.	Mean R.A. 1888 Jan. 1.	Mean N.P.D. 1888 Jan. 1.	Notes.
			Arg. Z. + 22°, 331.		
			h m s	° ′ ″	
1888. Oct. 19	R.		2 14 53·90	67 5 11·00	
30	F. B.	7–8	53·90	11·14	
Nov. 21	R.		53·98	11·69	
		7–8	2 14 53·93	67 5 11·28	
			Arg. Z. + 20°, 388.		
Dec. 12	R.	9–8	2 17 30·03	69 5 40·63	
			Arg. Z. + 22°, 347.		
Nov. 22	F. B.	8–7	2 20 37·91	67 37 33·19	
Dec. 22	F. B.	8–7	37·99	32·31	
		8–7	2 20 37·95	67 37 32·75	
			Arg. Z. + 23°, 326.		
Oct. 20	F. B.		...	65 52 13·48	
1889. Jan. 1	R.		2 21 53·45	15·21	
			2 21 53·45	65 52 14·35	
			Arg. Z. + 22°, 354.		
1888. Oct. 22	R.		2 22 50·55	67 1 51·32	
23	F. B.		50·61	52·03	
Nov. 27	F. B.	6	50·58	52·40	
30	R.		50·63	53·60	
		6	2 22 50·59	67 1 52·45	
			Arg. Z. + 20°, 404.		
Oct. 30	F. B.	8–7	2 22 57·71	68 54 21·90	
Dec. 26	F. B.	8	57·59	21·02	
		8	2 22 57·65	68 54 21·46	
			Arg. Z. + 24°, 358.		
Oct. 15	R.		2 24 5·75	65 15 41·99	Estimation of Mag. Dec. 22 = 6–5.
17	R.		...	42·53	
19	R.		5·83	42·70	
1889. Jan. 7	W.		5·82	42·34	
		6–5	2 24 5·80	65 15 42·39	

Day.	Observer.	Obs. Mag.	Mean R.A. 1888 Jan. 1.	Mean N.P.D. 1888 Jan. 1.	Notes.
			Arg. Z. + 21°, 349.		
1888.			h m s	° ′ ″	
Nov. 13	F. B.	7½	2 26 1·78	68 9 43·39	
20	F. B.	8–7	1·78	41·27	
22	F. B.	7½	1·75	42·91	
		8–7	2 26 1·77	68 9 42·52	
			Arg. Z. + 24°, 369.		
Nov. 26	R.	8	2 28 11·79	65 35 55·67	
Dec. 12	R.	8	11·81	54·71	
13	F. B.		...	55·07	
26	F. B.	8–9	11·89	54·21	
		8	2 28 11·83	65 35 54·92	
			Arg. Z. + 22°, 368.		
Oct. 20	F. B.		2 28 16·68	67 31 24·62	
Nov. 27	F. B.	8–9	16·65	22·02	
Dec. 22	F. B.	9–8	16·59	24·21	
		9–8	2 28 16·64	67 31 23·62	
			Arg. Z. + 22°, 372.		
Oct. 17	R.		...	67 26 10·86	
19	R.		2 30 18·74	10·41	
Nov. 22	F. B.	8	18·67	11·08	
		8	2 30 18·70	67 26 10·78	
			Arg. Z. + 24°, 376.		
1889. Jan. 1	R.		2 30 33·05	65 50 26·13	Second and brighter of two stars observed.
			Arg. Z. + 22°, 375.		
1888. Nov. 13	F. B.	8–9	2 31 25·36	67 21 25·99	
20	F. B.	8–9	25·39	24·59	
		8–9	2 31 25·38	67 21 25·29	

Mean Places of Iris Comparison Stars.

Star's Name.	Mag.	Mean R.A. 1888, Jan. 1.	No. of Obs. in R.A.	Mean N.P.D. 1888, Jan. 1.	No. of Obs. in N.P.D.
		h m s		° ′ ″	
Arg. Z. + 17°307	7·0	1 57 33·98	3	72 17 6·98	3
+ 17·315	7·3	2 1 36·99	2	72 30 15·33	3
+ 16·247	6·8	2 3 13·97	3	73 18 3·79	4
+ 19·329	7·5	2 3 29·95	1	70 10 57·54	2
+ 18·277	6·0	2 4 25·08	2	71 1 42·61	2
+ 20·341	7·5	2 5 6·07	1	69 9 1·59	1
+ 21·298	8·5	2 6 2·98	1	68 32 33·73	1
+ 20·348	5·5	2 6 31·89	3	69 18 55·13	3
+ 21·317	8·3	2 11 26·17	2	67 51 26·27	2
+ 19·340	6·0	2 11 53·77	6	70 37 2·08	6
+ 21·321	8·0	2 12 16·80	2	68 37 10·07	2
+ 22·329	6·0	2 12 38·61	1	67 20 57·78	1
+ 19·346	8·5	2 14 17·96	2	70 23 24·20	2
+ 22·331	7·8	2 14 53·93	3	67 5 11·28	3
+ 20·388	8·5	2 17 30·03	1	69 5 40·63	1
+ 22·347	7·8	2 20 37·95	2	67 37 32·75	2
+ 23·326	8·6	2 21 53·45	1	65 52 14·35	2
+ 22·354	6·0	2 22 50·59	4	67 1 52·45	4
+ 20·404	7·5	2 22 57·65	2	68 54 21·46	2
+ 24·358	6·2	2 24 5·80	3	65 15 42·39	4
+ 21·349	8·0	2 26 1·77	3	68 9 42·52	3
+ 24·369	8·2	2 28 11·83	3	65 35 54·92	4
+ 22·368	8·1	2 28 16·64	3	67 31 23·62	3
+ 22·372	7·6	2 30 18·70	2	67 26 10·78	3
+ 24·376	7·0	2 30 33·05	1	65 50 26·13	1
+ 22·375	8·3	2 31 25·38	2	67 21 25·29	2

Observers: W.—Mr. W. Wickham; R.—Mr. W. H. Robinson; F. B.—Mr. F. A. Bellamy.

Radcliffe Observatory, Oxford:
1889, *May* 9.

Ephemeris for Physical Observations of the Moon. By A. Marth.
1889 July 1 to 1890 January 1.

(Continued from p. 140.)

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Sel. Long. of the Earth.	Lat. of the Earth.	Geocentric Libration. Amount.	Direction.
1889.	°	°	°	°	°	°
July 1	309·27	−0·08	−4·93	−3·61	6·11	126·3
2	321·52	0·05	5·92	4·77	7·59	129·0
3	333·76	−0·03	6·68	5·71	8·78	130·7
4	345·99	+0·00	7·17	6·39	9·59	131·9
5	358·22	+0·03	7·34	6·77	9·97	132·9
6	10·45	0·05	7·14	6·80	9·85	133·8
7	22·66	+0·08	−6·57	−6·45	9·19	134·7
8	34·87	0·11	5·60	5·70	7·99	135·7
9	47·07	0·14	4·28	4·58	6·27	137·0
10	59·27	0·17	2·67	3·13	4·11	139·6
11	71·47	0·20	−0·86	−1·45	1·68	149·4
12	83·66	0·23	+1·04	+0·35	1·09	288·6
13	95·85	0·26	2·87	2·11	3·56	306·4
14	108·04	+0·29	+4·52	+3·71	5·84	309·5
15	120·23	0·32	5·85	5·03	7·71	310·8
16	132·43	0·35	6·81	6·00	9·06	311·6
17	144·63	0·38	7·33	6·59	9·84	312·2
18	156·84	0·41	7·41	6·81	10·05	312·8
19	169·06	0·43	7·09	6·68	9·73	313·5
20	181·28	0·46	6·40	6·24	8·93	314·4
21	193·51	+0·48	+5·43	+5·52	7·74	315·6
22	205·74	0·50	4·24	4·57	6·23	317·2
23	217·98	0·53	2·90	3·44	4·49	319·9
24	230·22	0·55	1·49	2·15	2·62	325·4
25	242·46	0·57	+0·07	+0·79	0·79	354·8
26	254·71	0·59	−1·29	−0·62	1·44	115·7
27	256·96	0·61	2·56	2·01	3·25	128·2

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Sel. Long. of the Earth.	Lat.	Geocentric Libration. Amount.	Direction.
1880. July 28	279°21	+0°63	−3°67	−3°33	4°96	132°2
29	291·46	0·66	4·62	4·50	6·45	134·4
30	303·71	0·68	5·35	5·49	7·66	135·8
31	315·95	0·70	5·87	6·22	8·54	136·8
Aug. 1	328·19	0·72	6·15	6·65	9·05	137·4
2	340·42	0·75	6·17	6·75	9·14	137·8
3	352·65	0·77	5·93	6·49	8·78	137·7
4	4·87	+0·80	−5·42	−5·86	7·97	137·3
5	17·09	0·82	4·64	4·87	6·72	136·5
6	29·29	0·85	3·59	3·56	5·06	134·8
7	41·49	0·87	2·31	2·01	3·06	131·1
8	53·69	0·90	−0·84	−0·31	0·90	110·2
9	65·88	0·92	+0·74	+1·43	1·60	333·2
10	78·06	0·95	2·34	3·06	3·85	322·7
11	90·24	+0·97	+3·83	+4·48	5·89	319·6
12	102·42	1·00	5·11	5·59	7·57	317·7
13	114·61	1·02	6·07	6·33	8·76	316·4
14	126·80	1·04	6·64	6·67	9·40	315·4
15	139·00	1·06	6·77	6·66	9·49	314·7
16	151·20	1·08	6·49	6·28	9·02	314·2
17	163·40	1·10	5·84	5·62	8·10	314·1
18	175·61	+1·12	+4·86	+4·72	6·77	314·3
19	187·83	1·13	3·65	3·63	5·15	314·8
20	200·05	1·15	2·30	2·39	3·31	316·1
21	212·27	1·16	+0·88	+1·05	1·38	320·1
22	224·50	1·18	−0·51	−0·33	0·60	122·8
23	236·74	1·19	1·79	1·70	2·47	133·5
24	248·97	1·21	2·91	3·02	4·19	136·0
25	261·21	+1·22	−3·82	−4·21	5·69	137·8
26	273·45	1·23	4·49	5·23	6·88	139·5
27	285·69	1·25	4·90	6·00	7·74	140·9
28	297·93	1·26	5·07	6·48	8·22	142·1
29	310·17	1·28	5·00	6·62	8·29	143·1
30	322·40	1·29	4·73	6·41	7·96	143·7
31	334·62	1·31	4·29	5·83	7·24	143·7

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Sel. Long. of the Earth.	Lat. of the Earth.	Geocentric Libration. Amount.	Direction.
1889.	°	°	°	°	°	°
Sept. 1	346·84	+1·32	−3·69	−4·92	6·14	143·2
2	359·06	1·34	2·95	3·70	4·73	141·5
3	11·26	1·35	·2·07	2·25	3·06	137·3
4	23·46	1·37	−1·07	−0·64	1·25	120·2
5	35·65	1·39	+0·03	+1·02	1·02	358·5
6	47·83	1·40	1·22	2·61	2·88	334·9
7	60·01	1·41	2·43	4·04	4·72	329·1
8	72·18	+1·43	+3·58	+5·21	6·32	325·6
9	84·36	1·44	4·58	6·04	7·57	322·9
10	96·53	1·45	5·34	6·49	8·39	320·8
11	108·70	1·46	5·78	6·56	8·74	318·8
12	120·87	1·47	5·86	6·28	8·57	317·2
13	133·05	1·48	5·54	5·68	7·93	315·8
14	145·23	1·48	4·87	4·82	6·85	314·8
15	157·42	+1·49	+3·89	+3·75	5·40	314·0
16	169·61	1·49	2·68	2·54	3·69	313·6
17	181·81	1·50	+1·32	+1·23	1·80	313·2
18	194·01	1·50	−0·09	−0·12	0·15	143·0
19	206·22	1·50	1·45	1·48	2·07	135·5
20	218·44	1·51	2·68	2·78	3·86	136·1
21	230·66	1·51	3·69	3·98	5·42	137·2
22	242·88	+1·51	−4·42	−5·01	6·68	138·7
23	255·10	1·51	4·83	5·82	7·56	140·4
24	267·33	1·52	4·92	6·35	8·03	142·4
25	279·55	1·52	4·70	6·54	8·05	144·4
26	291·78	1·52	4·23	6·37	7·64	146·6
27	304·00	1·52	3·55	5·83	6·82	148·8
28	316·22	1·53	2·75	4·93	5 65	151·0
29	328·43	+1·53	−1·88	−3·73	4·18	153·3
30	340·64	1·53	0·98	2·30	2·50	157·0
Oct. 1	352·84	1·53	−0·08	−0·73	0·73	173·4
2	5·03	1·54	+0·80	+0·89	1·02	318·0
3	17·21	1·54	1·68	2·46	2·97	325·7
4	29·39	1·54	2·53	3·86	4·62	326·8
5	41·56	1·54	3·34	5·03	6·04	326·5

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Sel. Long. of the Earth.	Lat. of the Earth.	Geocentric Libration. Amount.	Direction.
1889.	°	°	°	°	°	°
Oct. 6	53·72	+1·54	+4·07	+5·89	7·16	325·5
7	65·88	1·54	4·67	6·40	7·92	324·1
8	78·04	1·53	5·07	6·54	8·27	322·4
9	90·19	1·53	5·21	6·32	8·19	320·6
10	102·35	1·53	5·06	5·77	7·68	318·9
11	114·51	1·52	4·60	4·95	6·76	317·2
12	126·67	1·51	3·83	3·90	5·47	315·6
13	138·83	+1·50	+2·80	+2·70	3·89	314·0
14	151·00	1·49	1·56	1·39	2·08	311·8
15	163·17	1·48	+0·18	+0·03	0·18	279·6
16	175·35	1·47	−1·24	−1·33	1·82	137·2
17	187·54	1·46	2·60	2·63	3·69	135·4
18	199·73	1·44	3·81	3·83	5·40	135·3
19	211·92	1·43	4·77	4·89	6·83	135·8
20	224·12	+1·42	−5·42	−5·73	7·88	136·7
21	236·32	1·41	5·70	6·31	8·50	138·1
22	248·53	1·40	5·58	6·58	8·62	139·9
23	260·74	1·39	5·07	6·48	8·22	142·1
24	272·95	1·38	4·23	6·00	7·34	144·9
25	285·16	1·37	3·14	5·14	6·02	148·6
26	297·37	1·36	1·91	3·94	4·38	154·2
27	309·57	+1·35	−0·63	−2·48	2·56	165·9
28	321·77	1·34	+0·62	−0·86	1·06	215·5
29	333·96	1·33	1·76	+0·80	1·93	294·6
30	346·15	1·32	2·77	2·40	3·66	311·0
31	358·33	1·30	3·62	3·84	5·27	316·8
Nov. 1	10·50	1·29	4·32	5·03	6·63	319·5
2	22·67	1·28	4·86	5·92	7·65	320·8
3	34·83	+1·26	+5·23	+6·46	8·30	321·2
4	46·98	1·25	5·42	6·64	8·56	321·0
5	59·12	1·23	5·40	6·47	8·42	320·3
6	71·27	1·21	5·17	5·97	7·89	319·2
7	83·41	1·19	4·70	5·18	6·99	317·9
8	95·55	1·17	3·99	4·15	5·75	316·2
9	107·69	1·15	3·05	2·94	4·23	314·0

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Sel. Long. of the Earth.	Lat. of the Earth.	Geocentric Libration. Amount.	Direction.
1889. Nov. 10	119°83	+1°13	+1°90	+1°62	2°50	310°4
11	131·98	1·10	+0·60	+0·24	0·81	291·6
12	144·13	1·08	−0·80	−1·14	1·40	144·9
13	156·28	1·05	2·23	2·48	3·33	138·0
14	168·44	1·03	3·60	3·71	5·17	135·9
15	180·61	1·01	4·82	4·79	6·80	134·9
16	192·78	0·99	5·81	5·68	8·12	134·5
17	204·95	+0·96	−6·49	−6·33	9·05	134·5
18	217·13	0·94	6·77	6·68	9·50	134·8
19	229·32	0·92	6·63	6·69	9·41	135·5
20	241·51	0·90	6·04	6·32	8·74	136·5
21	253·71	0·88	5·04	5·58	7·51	138·0
22	265·91	0·86	3·70	4·43	5·77	140·2
23	278·11	0·84	2·12	2·99	3·66	144·7
24	290·31	+0·82	−0·43	−1·32	1·39	161·8
25	302·50	0·79	+1·24	+0·43	1·31	289·1
26	314·69	0·77	2·78	2·14	3·51	307·7
27	326·87	0·75	4·11	3·69	5·52	312·0
28	339·05	0·73	5·18	4·98	7·18	314·0
29	351·22	0·71	5·95	5·94	8·40	315·1
30	3·38	0·68	6·42	6·55	9·16	315·7
Dec. 1	15·54	+0·66	+6·60	+6·78	9·45	316·0
2	27·69	0·63	6·51	6·66	9·30	315·8
3	39·83	0·60	6·16	6·20	8·73	315·5
4	51·97	0·57	5·58	5·45	7·79	314·5
5	64·10	0·54	4·78	4·45	6·53	313·1
6	76·23	0·51	3·79	3·27	5·01	310·8
7	88·36	0·48	2·65	1·94	3·29	306·3
8	100·49	+0·45	+1·37	+0·55	1·48	291·9
9	112·63	0·42	0·00	−0·86	0·86	180·2
10	124·76	0·39	−1·41	2·23	2·64	147·7
11	136·90	0·36	2·82	3·50	4·50	141·2
12	149·04	0·33	4·16	4·63	6·23	138·1
13	161·18	0·30	5·37	5·57	7·74	136·2
14	173·33	0·27	6·38	6·28	8·94	134·7

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Sel. Long. of the Earth.	Lat. of the Earth.	Geocentric Libration. Amount.	Direction.
1889. Dec. 15	185°49	+0°24	−7°11	−6°71	9°77	133°6
16	197·66	0·21	7·49	6·83	10·12	132·6
17	209·83	0·18	7·47	6·60	9·96	131·6
18	222·00	0·16	7·02	5·99	9·22	130·7
19	234·18	0·13	6·11	5·01	7·90	129·5
20	246·37	0·11	4·80	3·69	6·05	127·6
21	258·56	0·08	3·14	2·09	3·77	123·6
22	270·75	+0·06	−1·26	−0·31	1·29	104·1
23	282·94	0·03	+0·72	+1·49	1·66	334·2
24	295·13	+0·01	2·63	3·18	4·13	320·4
25	307·32	−0·02	4·35	4·64	6·35	316·9
26	319·50	0·04	5·76	5·75	8·13	315·1
27	331·67	0·07	6·78	6·48	9·37	313·9
28	343·84	0·10	7·39	6·81	10·04	312·9
29	356·00	−0·13	+7·59	+6·76	10·15	311·9
30	8·16	0·16	7·40	6·36	9·75	310·9
31	20·31	0·19	6·87	5·66	8·90	309·7
1890 Jan. 1	32·45	−0·22	6·06	4·71	7·67	308·0

Errata in Gen. Tennant's paper, Vol. XLIX. No. 5.

Page 280, 8th line from bottom, *for* "fourth volume" *read* "second volume."
" 280, last line, *for* $a + bt^2$, *read* $a + bt$.
" 282, 15th line from bottom, *for* "value of *s*" *read* "value of *c*."

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIX. JUNE 14, 1889. No. 8

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

Alfred Fowler, Demonstrator of Astronomical Physics, Normal School of Science, South Kensington (proposed by J. Norman Lockyer);
Joseph Kleiber, Privat-Docent of the University of St. Petersburg, 53 Gr. Morskaia, St. Petersburg (proposed by J. W. L. Glaisher);
David Smart, L.R.C.P., M.R.C.S., L.S A., 108 Grange Road, London, S.E. (proposed by W. S. Franks).

The Photographic Spectrum of the Nebula of Orion.

By Dr. W. Huggins, LL.D., D.C.L., F.R.S.

(Extract from a letter to Mr. Knobel.)

"By photographs I have obtained nearly thirty new lines, and, what is perhaps of most interest, is that there are at least three groups of lines in the spectra of two of the stars of the trapezium which certainly extend, some more than others, into the adjoining nebular matter, and so show that these stars are not merely optically, but truly and physically connected with

the nebula. In another photograph taken a little distance from the trapezium, some of these lines appear to be absent, which suggests there may be a difference in the nebular spectrum in the *photographic region* (though not in the visible spectrum) between different parts, possibly more or less condensed, of the nebula. The bad weather prevented me from working out this point, and it is not more than a suggestion.

"The position of the brightest line which my former observations in 1864, 1871, and 1873 had fixed with great exactness, does *not* agree with that of the first line of the magnesium-flame band. I took very great pains during the winter to make a *direct comparison* of burning magnesium with the spectrum of the nebula: the result came out to confirm my early observations, and to show that the line of magnesium-flame band is *not* coincident with the line of the nebula.

"I therefore come to the provisional conclusion that so far as we know the nebula now is in a *state of gas*, though we have no knowledge of the *anterior* conditions which have brought it into this state."

The Spectrum of Uranus. By Dr. W. Huggins, LL.D., D.C.L., F.R.S.

(*Extract from a letter to Mr. Knobel.*)

"You may like to know an interesting new result I have just got. I have succeeded by photography in solving the question of solar lines in the spectrum of *Uranus*. With an exposure of two hours I got on June 3 a fine spectrum from about F to N in the ultra-violet. On the same plate a solar spectrum is photographed for comparison. In the spectrum of the planet all the principal Fraunhofer lines are distinctly seen, and I am unable to distinguish any other lines bright or dark. It is certain, therefore, that the light of the planet, for this region of the planet at least, is *solar*.

"In 1871 I sent a paper to the Royal Society, on the visible spectrum of *Uranus*, and gave a map and measures of six dark bands. I was unable, probably on account of the feebleness of the light, to catch the solar lines. In 1872 Vogel worked on the spectrum. He observed my bands, and he also failed to see any Fraunhofer lines." The weather since has not permitted me to observe again the *visible* spectrum.

The Spectrum of Saturn.

Before last week I took a number of spectra of *Saturn* and his rings. The slit so placed that the ansæ, ball and ring crossing it, give *separate* spectra, and the planet kept so absolutely on

the same part of the slit, that these spectra remain distinct, without encroaching on each other. I photographed *Saturn* in 1881, but as I saw Fraunhofer lines only I did not describe it. In my recent photographs the solar lines are well seen, and in these spectra, from about F to N, I am unable to detect any other lines bright or dark. *Saturn* was photographed before it was dark so as to give a very faint sky-spectrum for comparison.

Observations of the Spectrum of Uranus. By Albert Taylor, A.R.S.M., A.N.S.S.

(*Communicated by A. A. Common, F.R.S.*)

On Thursday, May 16, 1889, bright flutings were detected in the spectrum of the planet *Uranus*, by means of a small direct-vision star spectroscope, attached to the 5-foot reflector at Mr. Common's observatory at Ealing. The abundance of light obtained by the great aperture has allowed a more powerful spectroscope to be used since that date, micrometric measurements have been made of the positions of these flutings and bands, and of the dark bands in the spectrum of the planet, and the wave-lengths obtained by the reduction of these measurements are submitted to the Society in this paper.

Professor J. Norman Lockyer had telegraphed early in the month asking for the spectrum to be examined for bright flutings, and on first examination with the 5-foot the most striking features seen were four broad dark bands in the orange, green, greenish-blue, and blue respectively, and between these a series of bright flutings and bands, some of which were sharpest towards the red and others towards the blue end of the spectrum. This compound spectrum was also seen by Mr. Fowler, the demonstrator of astronomy at the Science Schools, South Kensington, who was on a visit to Ealing on May 16. The second dark band from the red end was seen to be the broadest, and was very strong, it and the narrower fourth band (the one in the blue about F) being very much darker than the remaining two. No trace of any solar line or of any narrow line in the spectrum was visible, although the spectrum was very bright, and the slit of the spectroscope was sufficiently narrow to show D as one sharply defined line in a Bunsen's burner (the dispersion being just sufficient to divide the D lines when the narrowest slit is used). As no measurements could be made with any degree of accuracy, and comparisons were difficult, independent light curves were drawn, and on comparison these were found to agree in all the main features. The curves are given in the drawing, and it will be seen that the four dark bands agree in relative position and width; the brightest part of the spectrum

is shown by each as in the green (subsequent measurements of positions giving 5190 as the wave-length), and two other great maxima are in perfect agreement. The only discrepancy between the two curves is in the yellow, and this was cleared up by observations at a later date. There are four submaxima indicated in my curve that Mr. Fowler omitted in his, but they were only seen with great difficulty and after resting the eye for some time.

On May 18 I was able again to observe the spectrum with the direct-vision spectroscope, and to confirm the light curve drawn on the 16th, with the exception of the region of previous discrepancy in the yellow, which I found should be as shown in the third curve. Several comparisons were also tried. The brightest fluting of carbon (517) was found to be nearly, but not exactly, coincident with the brightest fluting in the spectrum of *Uranus*, and the other carbon flutings (564 and 474) were seen to be very near bright flutings in the planet. The D lines of sodium fall near a faint dark band, but there is no dark marking or line of any kind exactly at that position in the spectrum of *Uranus*, neither was any other solar line visible, although fine lines were specially searched for. In the blue the spectrum was noted as faint and difficult to observe and represent, the bright bands sometimes appearing separated from the continuous spectrum. Several faint dark bands were seen in addition to the four broad absorptions.

On May 20 and 21, micrometric measurements were made of the dark bands and of the bright flutings and bands. The spectroscope used has one prism of 60°, and two of 30°, with automatic adjustment for minimum deviation. The collimator and observing telescope lenses are 1-inch aperture and $5\frac{1}{2}$ inches focus. The angular dispersion from A to H is 5°, and the eye-piece used magnifies fifteen times. The micrometer has a screw of 100 threads to the inch, and the drum is divided into 100 parts, so that accurate measurements can be made to $\frac{1}{10000}$th of an inch.

With this spectroscope ten dark bands were seen and measured, five of these being very strong absorption bands. Fourteen bright bands and flutings were seen, the positions of twelve of them measured, and a light curve was drawn to show their relative brightness. On no occasion was any narrow line seen, the solar spectrum being found to be entirely absent, although the slit was adjusted to show the b lines divided in the spectrum of magnesium, and narrow lines were specially looked for in the spectrum. The wave-lengths of the limits of the broad dark bands and of the middle of each of the fainter dark ones and of the brightest portions of the bright bands are as follows:—

Dark Bands in the Spectrum of Uranus.

		Wave-lengths.
I.	Very faint dark band	... 6332
II.	Dark band stronger and broader than I.	... 6194
III.	Very faint band (broad)	... 6010
IV.	Very strong band, very broad and apparently of unequal intensity	Begins 5754 Max. 5740 Ends 5730
V.	Very faint and narrow, and close to a bright fluting	... 5543
VI.	Broad band, of equal intensity throughout ...	Begins 5428 Ends 5399
VII.	Rather narrow band at red edge of brightest fluting	Begins 5210 Ends 5200
VIII.	Strong rather broad band of equal intensity throughout	Begins 4868 Ends 4860
IX.	Fairly strong broad band, not so dark as either VIII., VI., or IV.	Begins 4614 Ends 4594
X.	Another faint band, very difficult to measure ...	Begins 4350 Ends ?

The wave-lengths are means of two determinations.

Bright Bands and Flutings.

		Wave-lengths.
I.	Bright fluting, fading towards blue	6170
II.	Bright band, fainter on red edge	5863
III.	Brightening at edge of a dark band, fades towards the red	5761
IV.	Very strong bright band, fairly sharp towards the blue, and fading slightly towards the red	5601
V.	Strong bright band, fading both ways, but most towards the red	5473
VI.	Faint bright band, fading out equally in both directions ...	5302
VII.	Brightest, strongest fluting, sharp on its red edge ...	5190
VIII.	Faint fluting, sharp on its red edge	5068
IX.	Strong fluting, sharp towards red	4826
X.	Faint fluting, sharpest on red edge	4741
XI.	Faint broad band fading both ways, but sharpest to the red	4510
XII.	Faint fluting, sharpest to red	4345
XIII.	Faint band seen occasionally, but not measured... about	4100

There is decidedly another fluting similar to II. in the extreme red (about 635), but it was too faint to be accurately measured. In each case the wave-length given is the mean of three determinations.

Light Curves of the Spectrum of Uranus.

Although the term "fluting" is used, it must not be taken as implying that any structure was seen in these bright bands, but rather that the band was sharper at or near one edge than the other. The light curve of the spectrum of *Uranus* has been checked on four nights since May 21, and the drawing of that date confirmed.

On May 21 Mr. Espin, observing at Wolsingham Observatory with his 17¼-inch reflector, saw the blue broken up into bright bands and dull shadings, but found it impossible to give the places of these details, if they exist, in a drawing. He was using two compound prisms before an eyepiece of 200 power. Definition good but twilight, and planet low. On May 31 Mr. Crossley saw the spectrum of *Uranus* in the direct-vision spectroscope on the 5-foot reflector at Ealing, and saw most decided bright flutings in the green, yellow, and red, but was not so positive about the blue end of the spectrum. Mr. Bicknell, on June 3, also saw the bright flutings in the green, yellow, and red.

Of course it is an exceedingly difficult matter, and one requiring the utmost care, to distinguish between a bright band and a contrast appearance when a spectrum contains broad dark bands, but the bright flutings in *Uranus* are quite distinct from contrast appearances, and are so prominent as to be unmistakable.

I find Dr. Huggins and Dr. Vogel, although they measured the positions of the dark bands, do not seem to have noticed the bright flutings; but Secchi, in his light curve, seems to have had a distinct impression of the brightest fluting. This latter is more marked in his drawing of the light curve of the spectrum of *Neptune*.

The presence of bright flutings in the visual spectrum of *Uranus*, and the absence of any trace of the solar spectrum (on which point all observers agree), indicate that we must considerably modify our ideas as to the physical condition of this planet (and most probably of *Neptune* also), for there can be very little doubt that it is to a large extent self-luminous. It is interesting, perhaps, in this matter to call attention to the fact that *Uranus* is of about the sixth magnitude, yet the photometric intensity of the light of the Sun at *Uranus* is only about $\frac{1}{380}$th of that at the surface of the Earth. Of course we know nothing whatever of the reflecting power of *Uranus*, but if the light is entirely solar the absence of solar lines in the fairly bright visual spectrum will be difficult to explain, whereas if the light is to a large extent intrinsic this absence is fully accounted for.

Comparison of the Spectrum, between C and D, of a Sun-spot, observed May 27, 1884, with another of May 7, 1889. By Rev. S. J. Perry, D.Sc., F.R.S., and Rev. A. L. Cortie.

As the observations of the spectra of sun-spots at the red end of the spectrum have been rare during the time of minimum, we give in the present paper the results obtained on May 6 and 7 of the present year. All the lines between D and *w.-l.* 6474·85, very near C, were carefully examined, and their widening estimated in tenths of the normal breadth of the respective lines. The instrument used was the Browning automatic spectroscope, a dispersion of twelve prisms of 60° being employed. The definition was good, and the lines were all identified on Ångström's map. The spot had appeared on the limb on May 5, and disappeared about the 11th. The general absorption on the 6th was moderate, and on the 7th the spot was evidently breaking up. The following table contains a comparison of these observations, with the spectrum of a sun-spot near the epoch of spot maximum, taken under precisely the same conditions on May 27, 1884. This latter spot was very black, with a dark general absorption. Its spectrum had been previously observed on April 4, and it had reached its quiet stage after two solar revolutions. In Table I. the first column gives the wave-lengths of the lines taken from the British Association Catalogue (1878), and in the second and third columns are the observed amounts of widening in the two spots. The lines seen bright in the chromosphere by Professor Young are marked by an asterisk. In the remarks, A., B., F., S., K., L. and D. refer to the maps and numbers of Ångström, Burton, Fievez, Piazzi Smyth, Kirchhoff, Liveing and Dewar. In Table II. are collected the results for the different metals. In drawing up this table the coincidences have been taken from Ångström's map, and the British Association Catalogue (1878). A few lines also have been admitted from Watts' Index of Spectra, when the positions were very close, always less than one tenth-metre.

TABLE I.

Lines between C and D observed in two Sun-spots.

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
6562·10 C	0	0	
45·40	0·4	...	
*15·80	0·5	...	
11·64	...	...	
6498·25	0·6	...	
*96·31	0·4	...	

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
94·18	...	...	
92·41	0·4	...	
90·07	0·4	...	
81·18	0·5	...	
79·01	0·5	...	Comparison of the two spots begins.
74·85	...	0·8	
71·85 } 70·75 }	0·3	1·0	Seen as single.
68·78	0·5	1·0	
67·14	0·3	...	
63·74	0·8	...	
*61·98	0·4	1·0	A basic line. Resolved by L. and D. *Fe* the less refrangible. F. resolves. Seen as double with 12 prisms.
*54·0	0·5	0·8	A double.
	1·0	...	Faint line.
49·29	0·4	1·0	*Ca* more refrangible: L. and D.; F. resolves.
38·35	0·4	0·7	*Cd* more refrangible: L. and D.; F. does not resolve.
31·73	...	0	
*30·12	0·2	1·0	
20·63	0·2	0·6	
19·17	0·3	0·6	
*15·90	0·5	0·3	
14·10	0·5	0·3	
10·62	0·5	0·5	
07·38	0·4	0·5	*Fe* more refrangible: L. and D.; F. resolves. Seen as double with 12 prisms.
		0·8	Faint line.
		0·8	Faint line.
*6399·28	0·3	0·5	
		0·5	A double, about 6383·5 F.
*92·87	0·2	0·5	Both F. and S. draw as a double. Often so seen.
79·99	0·4	0·3	
77·58	0·3	...	
	0·6	...	Probably F. 6369·5.
64·49	0·7	0·3	In A.'s catalogue. Not in his map.
61·41	0·5	0·3	
57·92	0·3	0·2	
54·28	0·3	0·2	

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
		1·0	A double.
*6346·34	0·3	0·4	
43·40	0·2	0·5	
38·21	0·2	0·3	
36·61	0·2	0·3	
34·54	0·2	0·3	
	0·8	1·0	Not in A.
	0·7	1·0	Not in A. Probably B. 6327·0.
21·81	*d*	0·5	Only darkened May 27, 1884.
18·41	0·4	0·3	
17·17	0·4	0·6	
14·18	0·4	0·4	
09·78	0·5	0·5	May 6, 1889. Double or triple. A. draws as a faint line.
05·0	...	0·5	Wave-length doubtful. A double. F. has the line.
01·88	1·0	0·3	Black and close double.
01·03	0·1		
00·5	...	0·3	In A.'s map. Not in his catalogue.
6298·74	0·4	0·3	
96·95	0·4	0·5	
	d	...	Probably K. 801·5. Darkened May 27, 1884.
94·27	0·4	0·4	A double. A. has a line at 6293·5 in his map.
91·78	0·3	0·5	
90·31	0·3	0·4	
86·69	0·8	0·2	
84·99	1·0	0·6	
81·81	0·6	0·8	May 6, 1889. Three well-marked lines seen in the *a* group, surrounded by a hazy band.
79·79	0·5	0·8	
77·09*a*	0·3	0·4	
76·32?	1·0	1·0	A faint line just preceding a group.
70·16	*d*	0	
69·35	*d*	0·5	
	1·0	...	
	1·0	...	
64·31	0·3	0·3	
62·68	...	...	May 6, 1889. Could not be seen at all.
60·37	0·5	...	
57·84	0·8	1·0	Close double.

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
55·51	0·4	0·8	
53·40	0·4	0·8	
51·76	0·4	0·8	
46·55	0·4	0·6	
*45·62		0·6	
43·49	0·5	0	
42·60		3·0	May 6, 1889. Very much widened on more refrangible side.
40·51	0·5	1·0	Double seen as one line.
39·42			
*37·55			
37·09	0·3	0·8	Triplet hard to separate in spot. Has a fuzzy appearance.
36·33			
*6231·72	0·4	0·5	
29·91	0·2	0·6	
28·35	0·5?	1·0	
25·62	0·8	0·8	
22·57	1·0	0·8	
21·10	1·0	0·8	
*18·46	0·3	0·5	
15·67	0·5	1·0	
*14·30	0·5	0·6	
12·55	0·2	0·8	
09·3	1·0	...	A line in A.'s map, but neither in his nor B.'s catalogue. Could not be seen May 6, 1889.
	0·8	...	F 6203·5.
*6199·85	0·3	0·5	
	1·0	1·0	Faint line not in A.
*90·71	0·4	0·5	
87·26	0·8	0·8	
	0·8	0·8	6185·4 in A.'s map; not in his catalogue.
	1·0	1·0	Faint line. F 6182·0?
79·46	0·4	0·5	
75·95	0·5	0·5	
74·51	0·5	0·6	
72·49	0·2	0·5	
69·59	0·5	0·6	
*68·48	0·5	0·8	
65·62	0·8	2·0	Widened very much in penumbra, May 6, 1889.

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
63·95	0·8	1·0	
62·69	0·5	0·5	
*61·40	0·3	0·6	
60·23	0·8	0·8	
56·90	0·2	0·5	
54·41 53·89 53·33	0·5	0·8	A close triplet. Difficult to separate in spots.
50·68	0·5	0·5	
	1·0	0·8	Not in A. or F.
*48·28	0·2	0·5	
*46·76	0·2	...	Line could not be seen at all, May 6, 1889.
44·09	0·2	0·8	
*40·81	0·1	0·6	
36·82	0·2	0·6	
*35·82	0·2	0·6	
	1·0	2·0	Faint spot line. Not in A. or F.
30·59	0·4	0·8	
28·61	0·2?	0·8	
27·00	0·5	0·5	
25·29	0·5	0·8	
23·92	0·2?	0·8	
*21·34	0·4	0·5	*Co* less refrangible: L. and D. F. does not resolve.
6118·93	0·5	0·8	Very faint line.
15·51	0·3	0·3	*Ni* lines sharp, thin, dark lines.
*10·11	0·5	0·8	
07·36	0·2	0·3	
04·58	1·0	0·8	
*01·92	0·4	0·6	*Ca* more refrangible: L. and D.
6099·08	0·6	0·5	
95·20	0·3	0·5	The identification of the group of faint lines between 6101·92 and 6077·8 is somewhat doubtful. A. gives ten lines, K. eleven, B. twelve, F. sixteen, and S. eighteen. With 12 prisms and excellent definition, fourteen lines have been seen, the grouping agreeing much more with the map of S. than with that of F.
92·42	0·5	...	
90·59?	0·5	1·0	
88·42	0·5	...	

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
86·69	0·5	0·7	
85·1	*a*	0·5	
*84·0?	0·6	0·5	
81·3	0·5	0·5	
80·4	0·5	0·5	
77·80	0·3	0·5	F. doubles.
75·87	0·5?	...	Not seen, May 6, 1889.
*64·70	0·4	0·4	*Fe* less refrangible: L. and D. F. doubles.
	1·0	1·0	6061·7 F.
55·29	*a*	0·3	
53·28	0·8	0·8	
		1·0	Spot line 6044·79 F.
41·37	0·2	0·3	
	1·0	2·0	6039·4 F.
26·14	0·4	0·5	
23·16	0·3	0·5	
20·91	0·5	0·5	
*19·33	0·3	0·5	A double, F. 933·8 K.
15·81	0·4	0·5	
12·68	0·5	0·5	
11·42	...	1·0	
07·65	0·4	0·2	
07·2	...	0·4	B.'s catalogue. 940·4 K.
		1·0	Spot line about *w.-l.* 6004.
02·25	0·4	0·2	
	1·0	1·0	A. has a *Ti* line in map at 5998·5, but not in his or B.'s catalogue.
5997·08	0·5	0·2	
96·44	...	...	
*90·20	...	0·4	Generally not able to separate.
89·89	...		
88·10	...	0·4	A double.
86·35	0·4	0·2	
84·35	0·8	·3	
83·01	0·8	0·2	
77·27	1·0	1·0	
76·23	0·3	0·3	
74·79	0·5	0·3	
5970·44	...	0·3	
69·22	...		

Wave-length.	1884, May 27.	1889, May 6 and 7.	Remarks.
67·35	0·8	0·5	
65·9	0·8	0·5	In A.'s map, but not in his catalogue.
57·22	0·3	0·3	
55·63	...	0·5	
53·94 ?	...	1·0	
51·96	0·5	0·5	
47·62	0·5	0·3	
45·	...		
44·98	...	0·5	
43·62	...		
41·71	...		
40·9	...	0·5	Marked in A.'s map, but not in his catalogue.
40·43	...		
37·44	...	0·8	
34·03	0·5	0·3	
31·76			
31·18	1·0	0·5	Drawn slightly out of position in A.'s map.
29·46	0·2	0·3	
27·37	0·2	0·5	
24·02			Two lines generally seen as one thick one.
22·99	0·5	0·5	
21·69	0·5		
20·87	...	...	In A.'s map and catalogue, and in B.'s catalogue, but not seen.
19·09			
18·4	0·5	0·5	A dark band 5918·4 is not marked in A.'s catalogue, but in his map.
17·51			
14·60	0·5	0·8	
*13·30	0·2	0·1	
09·72	0·7	...	
04·56	0·5	0·2	A bright line or space about 5900. May be the effect of contrast.
5899·10	0·8	0·2	
*95·13	0·3	0·4	
92·10	0·4	0·2	
90·78	...	0·5	
*89·12	0·3	0·4	

TABLE II.

Lines widened one-half or more of their normal breadth.

Substance.	1884, May 27.	Bright in Chromosphere.	1889, May 6 and 7.	Bright in Chromosphere.
Iron	8	0	27	10
Titanium	12	1	12	2
Sodium	2	0	2	0
Calcium	3	1	8	5
Barium	2	1	4	3
Nickel	1	0	1	0
Manganese	2	0	3	0
Strontium + Fe	0	0	1	0
Cobalt + Ca	0	0	1	1
Antimony + Fe	0	0	2	1
Lithium + Ca	0	0	1	1
Cadmium + Ca	0	0	1	0
Zinc	1	0	0	0
Unknown	12	1	18	1
Unknown and faint	44	1	48	0

The above tables show that the widening of the faint unknown lines of the solar spectrum is common to the minimum and to the maximum sun-spot period. We would especially call attention to the faint lines at *w.-l.* 6039·3 F, 6053·28 A, and 6061·7 F, which are hardly traceable in the ordinary spectrum, and yet have been considerably widened in both sun-spots.

On the other hand the number of metallic lines which are among the most widened lines is much greater in the minimum than in the maximum spot. In the case of iron, for instance, the numbers are as 27 to 8. Again, none of the most widened iron lines of the maximum sun-spot have been recorded as bright in the chromosphere, while no less than ten of these lines in the minimum spot have coincident bright lines. The total number of lines seen bright in the chromosphere, which have also been observed among the most widened lines in the two spots, are for the maximum spot only five, but for the minimum spot twenty-four.

Another noticeable difference is that some lines of the maximum spot were widened far out into the penumbra, the most marked being *w.-l.* 5892·10, 5977·27, 6172·49, F. 6039·4, and F 6203·5. But in the minimum spot only one line was thus affected, 6165·62.

In Ångström's map there is a line at *w.-l.* 6209·3, of about intensity 2 of Kirchhoff's scale. This line is not in his catalogue

nor in that of the British Association, nor is it drawn in the maps of Kirchhoff, Piazzi Smyth, or Fievez. It could not be seen on May 6, and was again carefully searched for with the same result on May 21, 1889. Yet it is marked as widened in the spot of May 27, 1884.

The Nebula G. C. 2091. By E. E. Barnard, M.A., Astronomer of the Lick Observatory.

In the *Observatory* for April 1885 Mr. Sadler called attention to this nebula, and brought forward seemingly strong proof of motion. This is the nebula in which the double star *h* 2529 was observed, according to Sir John Herschel, twice in 1830 and once in 1831.

The nebula has also been observed by D'Arrest, and at Parsonstown; but it is not clear from the records that any of the observers since Herschel saw the double star to recognise it as such, though it is mentioned by them.

Mr. Burnham observed this nebula in 1879 and 1882, and measured the position-angle and distance from the tenth-magnitude star south of it. His measures are:

1879·225	8°·3	18″·96
1882·195	7°·5	18″·96

He estimated the magnitude of the star as 10, and the nebula as 12.

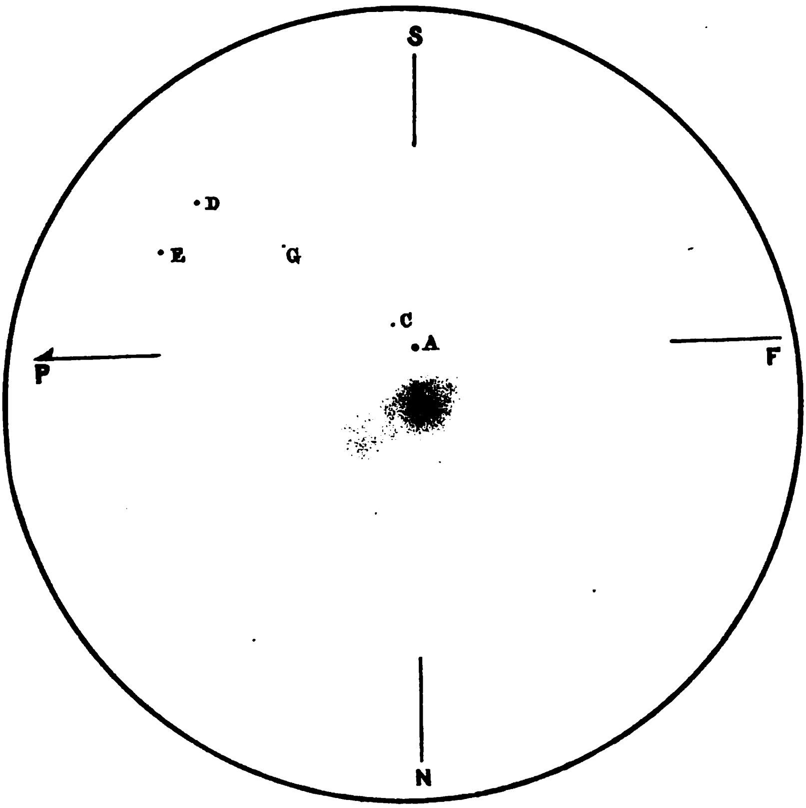
On March 5 of this year I examined the nebula with the 12-inch, and measured the position-angle and distance from the tenth-magnitude star—

1889·178	7°·8 (5 Obs.)	18″·96 (6 Obs.),

the distance coming out singularly enough the same as Mr. Burnham's two measures.

The nebula was small, round, and brighter in the middle, and quite easy to measure. I estimated the equivalent light to be of the twelfth magnitude.

On March 21, 23, and 24 Mr. Burnham and I examined this nebula with the 36-inch refractor. It was found to have an extension preceding and slightly north. This resembled a faint tail and was about 25″ long. In this extension was a faint condensation, which at first gave the appearance of a distinct nebula separated from the principal one. There was also a very faint extension for 10″ following and slightly south. Several times an excessively faint and difficult nucleus was seen, which did not appear to be stellar. A very faint star was thought to be involved in the preceding end of the tail, but it could not be seen steadily enough to make its existence certain. On each night the tenth-



The Nebula G.C. 2091, 1889 March 23.
36 inch Refractor. E.E. Barnard.

magnitude star was carefully examined by Mr. Burnham and myself; and Mr. Burnham is certain it is not now double, and that there is no double star about the nebula.

On March 23 I made a careful sketch of the nebula and of all the stars that could be seen in the field, which I here submit. The magnifying power used was 390. Some estimates were also made of the brightness of the objects shown in the sketch.

Mr. Burnham estimated A as 10th magnitude and C as 13th magnitude, which were about the magnitudes I should have assigned them. From my estimations the centre of the nebula was less bright than A, and was just perceptibly brighter than C.

The southern limit of the nebula, as near as I could estimate, was exactly one-half the distance from the nucleus to the star A. The star D is brighter than C, but less than E. The small star G is of the 14th magnitude, or fainter. No other stars besides those drawn were visible near the nebula or the star A.

In examining the region near the nebula on March 23 Mr. Burnham found a small double star $1^{m}\ 38^{s}$ *p.* and $2' \pm$ south of the nebula, which he estimates: Distance $1\frac{1}{2}''$; Pos. Ang. $160°$; Mag. $8 - 11$. This star is DM. $+13°$ 2244.

On June 7 I referred the tenth-magnitude star to the star Schj. 3813–14 with the filar micrometer of the 12-inch equatorial.

$10^{m} \star$ – Schj. 3813–14; $\Delta\alpha = -1^{m}\ 15^{s}{\cdot}13$ (6 Obs.); $\Delta\delta - 10'\ 7''{\cdot}5$ (3 Obs.).

This gives the place of the small star

$$\alpha\ 1889{\cdot}0 \quad = 10^{h}\ 17^{m}\ 48^{s}{\cdot}58 \qquad \delta\ 1889{\cdot}0 = +13°\ 7'\ 25''{\cdot}7.$$

From my position-angle and distance I get

$$\text{neb.} - 10^{m} \star \qquad \Delta\alpha = +0^{m}\ 0^{s}{\cdot}18 \qquad \Delta\delta = +0'\ 18''{\cdot}8,$$

and the resulting place of the nebula G. C. 2091

$$\alpha\ 1889{\cdot}0 = 10^{h}\ 17^{m}\ 48^{s}{\cdot}76 \qquad \delta\ 1889{\cdot}0 = +13°\ 7'\ 44''{\cdot}5.$$

On this occasion with a bright Moon the nebula was easily seen, but the star C with great difficulty. This star under favourable circumstances is easy in the 12-inch.

Whether the proper interpretation has been given to the earlier descriptions it is perhaps impossible to say, but the more recent observations do not indicate any change, and seem to justify the inference that there may be some question of the identification of the nebula, since it is wholly impossible that the double star should have disappeared absolutely, or that the nebula and star should have changed and subsequently remained fixed.

The present drawing shows faithfully all that can now be seen with the 36-inch, and will aid hereafter in deciding whether any change has really taken place.

Mount Hamilton: 1889, *June* 8.

Note on the Nebulous Star in Mr. Roberts's Photograph of 81 *and* 82 *Messier.* By Herbert Ingall.

At the April meeting of the Society some discussion ensued on the so-called nebulous star in this photograph, and the idea appeared to be put forth that it was either new or was *really* the nebula—mentioned by Sir William Herschel near 81 M., but queried in the Gen. Cat. as probably a mistaken entry of 81 M., and omitted in the new Gen. Cat. of Dreyer as certainly an error. As I have not heard of any further views on the subject I thought it might be well to try and identify the nebula. It is Gen. Cat. No. 1982 (=286 H I), and there described as "cB; cL; mbM; R. with ray." In the "Notes on Nebulæ" that I have contributed from time to time to the *Eng. Mech.*, I find that I observed it November 28, 1875, as "a moderately bright diffused nebula, 4′ *s.f.*, a bright 7 mag. star, round," and brightening to a rather condensed nucleus, but scarcely stellar; and on November 30 I say, "Dark night, nebula as above." I could detect no "ray" as mentioned by Herschel, and in a recent glance in a twilight sky the object was very diffuse and rather faint.

The extraordinary difference of its appearance in the photo-print (I have not seen the negative), and in the telescope is worthy of remark. In the latter the bright starlike aspect is entirely wanting, and it will be observed that the observations generally agree as to its aspect to the eye. D'Arrest says, October 9, 1862, only "much brighter round the middle," and again, August 12, 1866, "Subrotunda cum nucleo satis delicato ✳ 11," but whether he means a star, or equal to 11 mag. ✳, is not quite clear to me.

The place of Sir William Herschel's doubtful nebula would be near the centre of the photograph, where certainly there is no trace of nebula now.

On the Orbit of Sirius. By J. E. Gore.

The components of this interesting binary are now approaching their minimum distance, and the companion is rapidly becoming a very difficult object to measure, even with the largest telescopes. Using all the measures I could obtain from the date of its discovery by Alvan Clark, early in 1862, down to a measure made by Mr. Burnham with the Lick refractor at the close of last year, I have computed the orbit by the following method:—

Having plotted all the observations (corrected for precession to 1880·0) and drawn the interpolating curve, and the apparent ellipse in the usual way, I computed, by Professor Glasenapp's

method (*Monthly Notices*, March 1889), the values of the coefficients in the general equation of the second degree—

$$\alpha x + \beta y + \gamma x^2 + \delta xy + \epsilon y^2 + 1 = 0,$$

and obtained the following results:—

$$\alpha = -0{\cdot}001486$$
$$\beta = +0{\cdot}0067904$$
$$\gamma = -0{\cdot}00009408$$
$$\delta = +0{\cdot}0000827$$
$$\epsilon = -0{\cdot}0000677$$

These values were then substituted in Kowalsky's equations:—

$$\frac{\tan^2 i}{q^2} . \sin 2\Omega = \delta - \tfrac{1}{2}\alpha\beta$$

$$\frac{\tan^2 i}{q^2} . \cos 2\Omega = (\gamma - \epsilon) - \tfrac{1}{4}(\alpha^2 - \beta^2).$$

$$\frac{2}{q^2} + \frac{\tan^2 i}{q^2} = -(\gamma + \epsilon) + \tfrac{1}{4}(\alpha^2 + \beta^2).$$

$$e \sin \lambda = -\frac{q}{2}(\beta \cos \Omega - \alpha \sin \Omega) \cos i.$$

$$e \cos \lambda = -\frac{q}{2}(\beta \sin \Omega + \alpha \cos \Omega).$$

$$a = \frac{q}{1 - e^2}.$$

From these the geometrical elements of the orbit were computed. The values of P and T were obtained by another method.

The following are the resulting elements, which must be considered as provisional until further measures are available:—

Elements of Sirius.

$P = 58{\cdot}47$ years	$\Omega = 49^\circ\ 59'$ (1880·0)
$T = 1896{\cdot}47$	$\lambda = 216^\circ\ 18'$
$e = 0{\cdot}4055$	$a = 8''{\cdot}58$
$i = 55^\circ\ 23'$	$\mu = -6^\circ{\cdot}156$

Assuming Gyldén's parallax for *Sirius*, $0''{\cdot}193$, the above values of P and a give

Sum of masses = 26·298 (Sun's mass = 1)

Mean distance = 44·45 (Earth's mean distance from Sun = 1)

The following is a comparison between the recorded measures and the positions computed from the above elements. The

observed position-angles have been corrected for the effect of precession to 1880·0.

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1862·08	A. Clark	85° ±	85°·23	° ...	10″	9″·03	+0″·97
1862·19	Bond	84·7	84·93	−0·23	10·07	9·07	+1·00
1862·2	Rutherford	85·1	84·90	+0·20	...	...	...
1862·2	Chacornac	84·7	84·90	−0·20	...	...	...
1862·23	Challis	85·1	84·82	+0·28	10·42	9·08	+1·34
1862·28	Lassell	84·0	84·68	−0·68	...	...	...
1863·08	Mitchell	78·6	82·47	−3·87	10·5	9·38	+1·12
1863·10	Rutherford	81·3	82·42	−1·12	...	9·38	...
1863·14	Marth	79·4	82·31	−2·91	10·60	9·39	+1·21
1863·15	Mitchell	79·7	82·29	−2·59	10·9	9·39	+1·51
1863·20	,,	79·3	82·16	−2·86	10·40	9·41	+0·99
1863·21	O. Struve	82·6	82·13	+0·47	10·14	9·41	+0·73
1863·23	Dawes	84·91	82·08	+2·83	10·0	9·42	+0·58
1863·24	Winnecke	79·8	82·06	−2·26	...	9·42	...
1863·27	Bond	82·9	81·98	+0·92	...	9·42	...
1864·15	Lassell	80·4	79·70	+0·70	9·53	9·70	−0·17
1864·21	,,	80·2	79·57	+0·63	9·67	9·72	−0·05
1864·22	O. Struve	79·6	79·54	+0·06	10·92	9·72	+1·20
1865·20	,,	77·3	77·32	−0·02	10·60	10·02	+0·58
1865·22	Forster	78·0	77·27	+0·73	10·78	10·02	+0·76
1865·24	Struve	73·8	77·22	−3·42	10·79	10·02	+0·77
1865·25	Tietjen	76·9	77·19	−0·29	...	10·03	...
1865·26	Engelmann	77·0	77·16	−0·16	9·0	10·03	−1·03
1865·26	Bond	76·1	77·16	−0·06	9·0	10·03	−1·03
1865·70	Struve	73·38	76·0	−2·62	12·91	10·13	(+2·78)
1866·08	Knott	77·18	75·14	+2·04	10·43	10·25	+0·18
1866·20	Tietjen	76·88	74·87	+2·01	10·97	10·28	+0·69
1866·20	Bruhns	...	74·87	...	10·74	10·28	+0·46
1866·20	O. Struve	75·28	74·87	+0·41	10·93	10·28	+0·65
1866·23	Wash. Obs.	74·38	74·81	−0·43	10·21	10·28	−0·07
1866·25	,,	74·38	74·77	−0·39	10·65	10·27	+0·38
1867·22	O. Struve	72·17	72·71	−0·54	10·98	10·52	+0·46
1867·24	Forster	72·37	72·67	−0·30	...	10·52	...
1868·24	Bruhns	69·57	70·54	−0·97	11·35	10·70	+0·65
1868·26	Engelmann	71·67	70·50	+1·17	10·95	10·70	+0·25
1869·10	Brünnow	74·76	68·81	(+5·95)	11·26	10·88	+0·38
1869·15	Vogel	73·66	68·72	(+4·94)	11·23	10·88	+0·35

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1869·20	Dunér	68°·76	68°·62	+0°·14	11″·17	10″·89	+0·28
1871·22	„	64·15	64·71	−0·56	10·92	11·15	−0·23
1871·25	Pechule	60·15	64·64	(−4·49)	12·10	11·15	+0·95
1872·18	Dunér	59·84	62·56	−2·72	11·0	11·24	−0·24
1872·24	Wash. Obs.	62·74	62·43	+0·31	11·55	11·24	+0·31
1873·22	Dunér	60·84	60·97	−0·13	10·57	11·27	−0·70
1874·14	Wash. Obs.	58·03	59·27	−1·24	11·39	11·26	+0·13
1875·19	Dunér	57·13	57·32	−0·19	10·73	11·21	−0·48
1875·23	Wash. Obs.	56·23	57·24	−1·01	11·47	11·21	+0·26
1877·17	„	52·81	53·55	−0·74	11·35	11·00	+0·35
1877·25	„	53·41	53·40	+0·01	10·95	10·98	−0·03
1877·93	Burnham	53·21	52·06	+1·15	10·71	10·83	−0·12
1877·97	„	52·41	51·98	+0·43	10·83	10·82	+0·01
1878·03	„	51·11	51·86	−0·75	...	10·81	...
1879·05	„	50·7	49·77	+0·93	10·44	10·62	−0·18
1879·75	Cinn. Obs.	46·5	48·30	−1·8	10·29	10·44	−0·15
1880·11	Burnham	48·3	47·42	+0·88	10·00	10·27	−0·27
1880·168	Hough	49·6	47·29	+2·31	9·87	10·26	−0·39
1881·07	Burnham	46·3	45·32	+0·98	9·77	10·01	−0·24
1881·12	Holden	43·3	45·20	−1·90	10·83	9·99	+0·84
1881·26	Wash. Obs.	45·3	44·86	+0·44	10·0	9·94	+0·06
1881·26	Hough	45·3	44·86	+0·44	9·60	9·94	−0·34
1881·99	Burnham	43·6	43·09	+0·51	9·38	9·67	−0·29
1882·127	Hough	43·1	42·75	+0·35	9·30	9·61	−0·31
1882·183	Frisby	42·24	42·61	−0·37	9·955	9·58	+0·375
1882·235	Hall	42·48	42·48	0·0	9·668	9·57	+0·098
1883·10	Young	38·99	40·67	−1·68	9·41	9·21	+0·20
1883·12	Hough	39·68	40·60	−0·92	9·02	9·20	−0·18
1883·17	Frisby	41·41	40·43	+0·98	9·754	9·17	+0·584
1883·211	Hall	39·08	40·29	−1·21	9·260	9·15	+0·11
1884·05	Hough	35·98	37·37	−1·39	9·67	8·72	+0·95
1884·179	„	36·68	36·98	−0·30	8·51	8·65	−0·14
1884·19	Burnham	36·38	36·95	−0·57	8·39	8·64	−0·25
1884·226	Hall	37·64	36·83	+0·81	8·81	8·62	+0·19
1884·273	Young	36·28	36·70	−0·42	8·70	8·60	+0·10
1885·11	Paris Obs.	34·07	33·85	+0·22	8·09	8·13	−0·04
1885·112	Young	34·03	33·85	+0·18	8·09	8·13	−0·04
1885·197	Hough	32·67	33·50	−0·83	7·96	8·08	−0·12
1885·268	Hall	34·70	33·25	+0·45	8·057	8·03	+0·027

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	"	"	"
1885·301	Hall	33·87	33·09	+0·78	7·93	8·01	−0·08
1886·047	Young	29·74	30·26	−0·52	7·59	7·57	+0·02
1886·14	Wash. Obs.	30·57	29·90	+0·67	7·21	7·51	−0·30
1886·144	Hough	28·67	29·88	−1·21	7·21	7·51	−0·30
1886·22	Wash. Obs.	28·66	29·53	−0·87	7·39	7·46	−0·07
1887·14	Young	25·36	25·32	+0·04	7·08	6·84	+0·24
1887·195	Hough	23·66	25·04	−1·38	6·78	6·80	−0·02
1887·238	Hall	24·14	24·82	−0·68	6·508	6·77	−0·262
1888·97	Burnham	13·85	13·96	−0·11	5·27	5·52	−0·25

I have computed the following short ephemeris:—

Epoch.	Position-angle.	Distance.
	°	"
1890·2	2·61	4·62
1891·2	349·68	3·95
1892·2	332·27	3·45
1893·2	310·88	3·23
1894·2	288·95	3·36
1895·2	270·37	3·78
1896·2	255·95	4·24

On the close Conjunction of Mars and Saturn near Regulus on September 19, 1889. By A. Marth.

The conjunction of *Mars* and *Saturn* predicted in the Almanacs for September 19, 20^h G.M.T., deserves special attention. The tabular places of the two planets give the nearest geocentric approach of their centres 54″·8 at 20^h 7^m Greenwich mean time, so that the conjunction will be a closer one than that of June 30, 1879, when the shortest distance between the nearest limbs was 74″, according to the Melbourne observations, *Monthly Notices*, vol. xl. p. 30. The next close conjunction preceding that of 1879 took place on April 18, 1817, but was not observable at any then existing observatory, and of any previous close conjunction there is at least no record.

The differences of right ascension and declination between *Titan* and *Iapetus* and the centre of *Saturn* will be

		Titan.		*Iapetus.*	
		$\alpha_s-A.$	$\delta_s-D.$	$\alpha_s-A.$	$\delta_s-D.$
	h	s	"	s	"
Sept. 19	16 Gr.	−7·81	−34·6	+11·54	−11·7
	20 „	7·25	35·0	11·12	11·5
20	0 „	−6·66	−35·2	+10·70	−11·3

Hence the geocentric differences between *Mars* and *Iapetus* will be

		$♂-\alpha_s$	$♂-\delta_s$
	h m	s	″
Sept. 19	22 0 Gr.	−0·30	+12·9
	10	+0·54	+ 8·5
	22 20	+1·38	+ 4·1

If these tabular values are not too much in error, observers in America may get the rare chance of observing, if not an actual occultation of *Iapetus* by *Mars*, at least a very close conjunction of the two bodies, which, even as a mere *curiosum*, will be worth attending to.

What renders this year's conjunction between *Mars* and *Saturn* specially remarkable and interesting, is the circumstance that it takes place not far from *Regulus*, the geocentric distance of *Mars* from the star being

	h		′ ″		°
Sept. 19	18 Gr.	Distance	47 57·3	Posit.-angle	5·74
	20 „		47 17·0		9·43
	22 „		46 48·8		13·24

and it has seemed to me worth while to examine when such a phenomenon has occurred before. On the occasion of an oral communication made at the June meeting of the Royal Astronomical Society in 1877, I showed some diagrams referring to triple conjunctions between *Mars* and *Saturn*, some of which were reproduced in the report published in the *Astronomical Register*, vol. xv. p. 156 ff. One of these diagrams exhibited the path of *Mars* relative to *Saturn* from November 1742 to June 1743, the third conjunction occurring on May 17, when *Mars* passed *Saturn* at a distance of 10′ to the south. On June 1 this conjunction was followed by a close conjunction between *Mars* and *Jupiter* at a distance of only 72″. Referring to Cassini's paper in the *Paris Memoirs* of 1743, p. 318 ff., and to the graphical representation there given, it will be found that *Regulus* formed with the planets a most interesting constellation, the star being at the time of the conjunction of May 17 only a couple of degrees distant. The planets were then to be seen in the evening.

The conjunction of *Mars* and *Saturn* near *Regulus* most nearly resembling that of the present year, when they are morning stars, must have occurred in the year 1447, but I am not aware that there exists any record of its having been observed. For a long period previous to 1447 no similar close conjunction has occurred.

The interest of the present year's conjunction is enhanced by another circumstance. On September 25 *Venus* will pass *Regulus* at a distance of 11′, and will, in the following week, come into conjunction with *Saturn* and with *Mars*.

If the old Chaldeans were in fact such diligent stargazers as they are sometimes represented, they must have been watchful in observing conjunctions of the planets with one another and with fixed stars, such as are to be found in the records of Chinese and of Arabian observers, which have been made accessible to us by Gaubil and by Caussin. The cuneiform inscriptions have not yet yielded up the secreted records of such observations, which would be of essential service in settling questions of their chronology. Perhaps some day the old Chaldean observations may yet be made accessible. But I doubt whether, however far they may go back, there will be found in them a combination of conjunctions resembling that of next September; for I question whether, since the beginning of Scaliger's Julian period or during the last six thousand years, any year can be found in which this special combination of conjunctions has occurred. Hence it will be worth while to be on the alert to observe it. And useful observations may be made with the naked eye. In the old records are found apparent occultations of *Mars* and of *Jupiter* by *Venus*, of *Jupiter* by *Mars*, of *Regulus* by *Venus* and by *Jupiter*, &c., but it is uncertain what are the limits of distance within which such bright bodies appear to the naked eye as one. Though no apparent occultation of *Saturn* by *Mars* is on record, the careful watching of the two planets and noting the times when, without undue straining of the eyes, they cease to appear separated, and when they begin again to appear so, will be of service in correctly interpreting the old observations. On September 19 the geocentric distance of their centres will be

within	$2'$	from	$18^{h}\ 44^{m}$	to	$21^{h}\ 30^{m}$ Gr. m. t.
	3	„	17 53	„	22 20
	4	„	17 4	„	23 9
	5	„	16 16	„	23 57

As the planets are only 30° from the Sun, the beginning and ending of the apparent occultation cannot be observed from the same place. But, as any trustworthy schoolboy or schoolgirl may be entrusted with taking part in the watching, there ought to be no lack of numerous observers of the phenomenon in favoured terrestrial longitudes. The opportunity may also be taken to watch when the planets and *Regulus* cease to be visible in the morning twilight, and by repeating the watching and observing the altered positions of the three planets and of the star on the following mornings to gain some instructive astronomical knowledge.

On the Eclipse of Iapetus by Saturn and its Ring-System, on November 1–2, 1889. By A. Marth.

The inclination of the orbit of *Iapetus* to the plane of the ring being nearly 14°, while the orbits of the other satellites have inclinations of less than 1°, the rare eclipses of *Iapetus* by the ring-system offer the only chance of deciding several questions which may be settled with the help of observed eclipses. No such observation has ever yet been made. Favourably-placed observers ought, therefore, to take full advantage of the rare chance they may get on November 1. There will not be another such chance for at least the next sixteen years.

The geocentric differences of right ascension and declination between *Titan* and *Iapetus* and the centre of *Saturn* will be from October 24 to November 4.

Greenwich Noon.	*Titan.* α_s-A.	*Titan.* δ_s-D.	*Iapetus.* α_s-A.	*Iapetus.* δ_s-D.
	s	″	s	″
Oct. 24	+ 1·60	−24·5	−23·73	+28·6
25	+ 5·90	−14·5	−21·79	+28·3
26	+ 9·31	− 2·4	−19·72	+27·8
27	+11·26	+10·0	−17·53	+27·2
28	+11·39	+20·8	−15·24	+26·4
29	+ 9·64	+28·1	−12·85	+25·4
30	+ 6·29	+30·7	−10·38	+24·3
31	+ 1·88	+28·2	− 7·84	+23·0
Nov. 1	− 2·84	+21·1	− 5·25	+21·5
2	− 7·14	+10·8	− 2·62	+19·9
3	−10·37	− 1·3	+ 0·04	+18·1
4	−12·09	−13·1	+ 2·70	+16·3

These values show that, while the Earth is still on the south side of the plane of the orbit of *Titan*, it has already passed through the plane of the orbit of *Iapetus*, and is on the north side of that plane. Hence *Titan* and *Iapetus*, though both being north of the planet, move apparently in opposite directions, *Titan* being in front of the planet, or near inferior conjunction, while *Iapetus* is beyond the planet, or near superior conjunction. On October 31, at $10^{h}\cdot5$ G.M.T., *Titan* passes in the direction of the minor axis of the ring at a distance of 26″ to the north. On November 1, at $8^{h}\cdot0$ G.M.T., *Iapetus* encounters

Titan, and passes at a distance of 3″. Not long after this conjunction, between 9^h and 10^h, *Iapetus* enters the shadow of the ring-system, from which it will emerge between 4^h and 5^h on November 2. As I am very desirous not to give more precise predictions which might be misleading, I will let interested readers judge for themselves by furnishing them with the data for constructing a diagram, which will show them the sources of uncertainty in predicting the times at a glance.

The section of the shadow, through which *Iapetus* has to pass, consists of a series of ellipses, corresponding to the outer and inner rims, A*a*, B*b*, C*c*, of the three rings, and to the outline of the ball. The heliocentric semi-axes of these ellipses, corresponding to various determinations of the dimensions of the rings and of the ball, are at the time of the eclipse:

	Major, Semi-axis.	Minor, Semi-axis.			Major, Semi-axis.	Minor, Semi-axis.	
A	20″·76	4″·03	W. Struve	*b*	13″·79	2″·67	W. S.
	20·33	3·94	Bessel		12·87	2·50	O. S.
a	18·25	3·54	W. S.	*c*	10·99	2·13	Bond
	18·16	3·52	O. Struve		10·76	2·09	O. S.
B	17·82	3·46	W. S.	ball	9·30	...	W. S.
	17·62	3·42	O. S.		8·22	8·00	Bessel

The computed heliocentric co-ordinates of *Iapetus*, referred to the axes of the ring, and corresponding to the lines when light from the satellite arrives at the Earth, are:

	h				h		
Nov. 1	8 Gr.	−16″·08	+3″·32	Nov. 1	20 Gr.	+ 4″·08	+0″·45
	12	− 9·36	+2·37	2	0	+10·80	−0·50
	16	− 2·64	+1·41		4	+17·52	−1·46
	20	+ 4·08	+0·45		8	+24·23	−2·41

What corrections these values may require I am unable to suggest. If I were acquainted with the observations of the satellite made during the last opposition, and could determine the errors of the last ephemeris, I might get nearer the truth. But it is clear that as an error of 1″ in the heliocentric longitude of the satellite corresponds to an error of 36 minutes in the time, considerable uncertainty must attach to any predicted times, to which the other sources of doubt add their share.

When used with the necessary caution of making proper allowance for this uncertainty, the following times may serve as a guide in preparing for the observations to be made:

Nov. 1	$8^{h}.0$	Gr. Iap. ☍ Tit.			
	9·4	„	Disappearance	A	W. S.
	9·6	„	„	„	Bessel
	10·6	„	? Reappearance	*a*	W. S.
	10·9	„	D.	B	O. S.
	22·8	„	R. from shadow of ball		Bessel
	23·1	„	„ „		W. S.
	23·8	„	enters shadow of crape ring.		
Nov. 2	1·4	„	D.	*b*	W. S.
	3·2	„	? R.	B	O. S.
	3·5	„	D.	*a*	W. S.
	4·5	„	R.	A	Bessel
	4·7	„	„	„	W. S.

Will *Iapetus* be visible when Cassini's division *a*B is between the satellite and the Sun? What will be the effect of the shadow of the crape ring upon the appearance of the satellite?

Favourably-placed observers will have to answer such questions by their watching the satellite, and their time will be well spent in doing so.

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Discussion of the Observations of the Sun made with the Washington Transit-Circle during the years 1875–1883 *inclusive.* By A. M. W. Downing, M.A.

The comparatively large discordances in existing determinations of the position of the equinox make it a matter of importance that the meridian observations of the Sun, made at the principal Observatories, should from time to time be discussed, and a determination of this element deduced from them. It is with this object in view that the discussion of the Washington Transit-Circle observations of the Sun made during the years 1875–1883 inclusive has been undertaken, and I have now the honour of communicating the results to the Society.

During the years mentioned the same reduction-elements have been used throughout, both for the observations of right ascension and of north polar distance. The adopted equinox is that of Newcomb's "Fundamental Equatorial Stars," used in the American *Ephemeris* since 1881. The observations of 1883 are the latest published.

The observations, as given in the several volumes of Washington Observations, have been combined by months, and the following table gives the mean day, the mean correction to the *Ephemeris* in R.A. and N.P.D. respectively, and the number of observations in each element on which the means depend. Those results only have been used which have been deduced from observations of *both* limbs of the Sun. The places of the Sun, with which the Washington observations were compared during these years, were taken from Hansen's and Olufsen's Solar Tables.

No.	Mean Date.	Correction to Ephemeris. R.A.	Correction to Ephemeris. N.P.D.	Number of Observations. R.A.	Number of Observations. N.P.D.
		s	″		
1	1875 Jan. 15	+0·063	+0·65	4	4
2	Feb. 15	+0·077	+0·60	7	7
3	Mar. 17	+0·039	+0·72	9	9
4	Apr. 17	−0·005	+1·14	6	6
5	May 20	−0·036	+1·29	11	11
6	June 18	−0·030	+1·68	8	8
7	July 14	+0·030	+0·80	2	2
8	Aug. 17	+0·065	+0·89	9	9
9	Sept. 12	+0·039	+2·04	7	7
10	Oct. 17	+0·110	+0·49	13	13
11	Nov. 14	+0·075	+0·62	10	9
12	Dec. 17	−0·089	+1·05	7	6
13	1876 Jan. 23	−0·050	+1·66	4	5
14	Feb. 16	+0·009	+0·55	9	11
15	Mar. 12	−0·023	+0·68	7	8
16	Apr. 13	+0·019	−0·18	11	10
17	May 15	−0·011	+1·10	7	9
18	June 17	−0·003	+1·01	7	7
19	July 16	−0·023	+0·98	13	13
20	Aug. 26	+0·087	+0·06	6	5
21	Sept. 16	+0·047	+0·25	6	6
22	Oct. 12	−0·016	−0·39	9	10
23	Nov. 10	+0·011	−0·10	8	9
24	Dec. 15	−0·058	−0·43	6	6
25	1877 Jan. 28	+0·063	+0·36	6	5
26	Feb. 13	+0·008	+1·44	10	10
27	Mar. 13	+0·050	+0·93	4	4
28	Apr. 11	+0·020	+0·68	4	5
29	May 14	−0·064	+1·97	5	6
30	June 16	−0·028	+1·80	5	6
31	July 18	−0·012	+2·02	5	5
32	Aug. 10	+0·150	+5·40	1	1
33	Oct. 9	+0·055	+0·45	2	2
34	Nov. 12	+0·064	−0·38	7	6
35	Dec. 13	+0·050	−0·85	3	4
36	1878 Feb. 15	−0·022	−0·52	6	6
37	Mar. 14	−0·017	−0·70	3	3
38	Apr. 14	−0·030	−1·30	8	8

No.	Mean Date.	Correction to Ephemeris. R.A.	Correction to Ephemeris. N.P.D.	Number of Observations. R.A.	Number of Observations. N.P.D.
		s	"		
39	1878 May 15	−0·022	+0·57	6	6
40	June 15	−0·050	+1·04	8	8
41	Sept. 20	−0·048	−0·61	6	7
42	Oct. 18	+0·050	+0·30	5	7
43	Nov. 12	+0·053	−1·17	9	9
44	Dec. 10	+0·030	+1·00	6	7
45	1879 Jan. 30*	+0·020	+2·30	1	1
46	Feb. 16	+0·082	+1·13	5	4
47	Mar. 6	+0·130	+0·05	4	4
48	Apr. 13	+0·010	+0·07	6	6
49	May 14	+0·053	+1·13	7	7
50	June 15	−0·009	+2·71	10	9
51	July 13	+0·019	+1·45	10	10
52	Aug. 13	0·000	+1·80	2	1
53	Sept. 17	+0·081	+1·78	7	8
54	Oct. 13	+0·166	+0·91	9	9
55	Nov. 17	+0·200	+1·72	5	5
56	Dec. 17	−0·010	+0·64	5	5
57	1880 Jan. 18	+0·040	+1·14	4	5
58	Feb. 14	−0·053	+0·42	6	5
59	Mar. 24	−0·053	+0·87	3	3
60	Apr. 19	−0·030	+1·20	4	4
61	May 16	−0·015	+2·06	10	8
62	June 18	+0·007	+1·70	3	1
63	July 20	+0·005	+2·85	4	4
64	Aug. 16	−0·033	+2·85	3	2
65	Sept. 16	−0·025	+2·50	8	5
66	Oct. 15	+0·032	+0·92	10	9
67	Nov. 15	+0·100	+2·57	3	3
68	Dec. 11	−0·023	+1·90	4	4
69	1881 Jan. 24	+0·095	−0·15	4	4
70	Feb. 16	+0·098	+1·59	9	9
71	Mar. 17	+0·010	+1·34	7	7
72	Apr. 22	−0·070	+0·78	5	6
73	May 24	−0·025	+1·63	6	6
74	June 20	−0·034	+1·87	7	7
75	July 15	−0·030	+1·87	11	12

* No. 45. An observation taken on 1879 Jan. 31, has been rejected.

No.	Mean Date.	Correction to Ephemeris. R.A.	Correction to Ephemeris. N.P.D.	Number of Observations. R.A.	Number of Observations. N.P.D.
		s	"		
76	1881 Aug. 17	−0·037	+2·03	6	8
77	Sept. 24	+0·100	−0·20	1	1
78	Oct. 18	+0·003	+0·57	9	10
79	Nov. 17	+0·036	+1·26	7	7
80	Dec. 15	−0·015	+1·15	6	6
81	1882 Jan. 27	−0·030	+0·15	3	2
82	Feb. 13	+0·011	+0·46	11	11
83	Mar. 13	+0·013	+1·15	4	4
84	Apr. 20	−0·073	+0·13	8	8
85	May 19	−0·035	+0·64	10	9
86	June 15	−0·002	+0·71	12	12
87	July 16	+0·047	+0·08	6	6
88	Aug. 16	+0·020	−1·65	4	2
89	Sept. 21	−0·018	−0·26	5	5
90	Oct. 9	+0·010	+0·17	3	3
91	Nov. 19	+0·043	+0·22	6	5
92	Dec. 10	+0·023	−0·30	4	3
93	1883 Feb. 22	−0·020	+2·65	6	6
94	Mar. 11	+0·018	+2·44	5	5
95	Apr. 13	−0·013	+2·35	3	4
96	May 14	−0·014	+1·55	9	11
97	June 14	−0·022	+1·86	6	5
98	July 11	−0·004	+1·93	8	8
99	Aug. 12	−0·088	+1·54	6	5
100	Sept. 6	−0·160	+0·40	1	1
101	Oct. 19	+0·023	+1·70	6	6
102	Nov. 14	+0·029	+1·23	10	11
103	Dec. 13	−0·114	+1·16	7	8

The next step has been to compute the corrections to tabular Ecliptic North Polar Distance from the corrections to tabular R.A. and N.P.D. These form the absolute terms in the following equations of condition.

The weights have been computed in the following way. Let R and S be the factors by which the corrections to tabular R.A. and N.P.D. must respectively be multiplied to give correction to tabular E.N.P.D., so that

$$\delta \text{E.N.P.D.} = \text{R}\,\delta\,\text{R.A.} + \text{S}\,\delta\,\text{N.P.D.}$$

Now let n be the number of observations of R.A. in a group, e the probable error of a single observation of R.A., n_1 the

number of observations of N.P.D. in a group, e_1 the probable error of a single observation of N.P.D., then the weight of each correction to tabular Ecliptic North Polar Distance has been computed from the formula

$$\text{Weight} = \frac{nn_1}{10(n_1 R^2 e^2 + n S^2 e_1^2)}, \text{ or (if } n = n_1),$$

$$\text{Weight} = \frac{n}{10(R^2 e^2 + S^2 e_1^2)}.$$

For convenience the latter formula has been used, and where n and n_1 are not equal their mean has been taken as the value of n. The values of e and e_1 have been found for each month throughout the series of years by taking the difference between the mean correction to tabular R.A. or N.P.D., as the case may be, for the month in each year, and each individual correction. The following values for the probable errors for each month have been thus obtained, and the "adopted" values, not differing much from them, have been used in the subsequent computations.

Month.	Probable Error in R.A. Computed.	Probable Error in R.A. Adopted.	Number of Observations.	Probable Error in N.P.D. Computed.	Probable Error in N.P.D. Adopted.	Number of Observations.
	s	s		″	″	
January	±0·071	±0·070	25	±0·63	±0·85	25
February	·067	·070	69	·94	·85	68
March	·042	·045	46	·76	·85	47
April	·042	·045	55	·88	·85	55
May	·043	·045	69	·65	·65	73
June	·049	·045	68	·64	·65	62
July	·054	·045	62	·63	·65	60
August	·043	·045	36	·79	·65	31
September	·045	·045	40	·62	·65	39
October	·047	·045	70	·68	·65	70
November	·068	·070	62	·94	·85	58
December	·063	·070	49	·96	·85	43

In the formation of the following equations of condition it has been assumed that the error of tabular Ecliptic North Polar Distance may be represented by

$$x \times \cos \text{Sun's longitude} + y \times \sin \text{Sun's longitude} + z.$$

No.	Equations of Condition.					Weights.	Residuals.
				″			″
1	$+\cdot4260x$	$-\cdot9047y$	$+z$	$+0\cdot800$	$=0$	4·0	+0·330
2	$+\cdot8355x$	$-\cdot5495y$	$+z$	$+0\cdot948$	$=0$	3·8	+0·262
3	$+\cdot9984x$	$-\cdot0573y$	$+z$	$+0\cdot893$	$=0$	6·9	−0·055
4	$+\cdot8889x$	$+\cdot4581y$	$+z$	$+1\cdot037$	$=0$	5·1	−0·168
5	$+\cdot5115x$	$+\cdot8593y$	$+z$	$+1\cdot149$	$=0$	19·7	−0·211
6	$+\cdot0523x$	$+\cdot9986y$	$+z$	$+1\cdot671$	$=0$	20·0	+0·284
7	$-\cdot3711x$	$+\cdot9286y$	$+z$	$+0\cdot724$	$=0$	4·1	−0·588

No.	Equations of Condition.					Weights.	Residuals.
8	$-{\cdot}8124x$	$+{\cdot}5831y$	$+z$	$+0''{\cdot}524$	$=0$	10·9	$-0''{\cdot}574$
9	$-{\cdot}9833x$	$+{\cdot}1822y$	$+z$	$+1{\cdot}649$	$=0$	6·8	$+0{\cdot}768$
10	$-{\cdot}9141x$	$-{\cdot}4054y$	$+z$	$-0{\cdot}146$	$=0$	13·9	$-0{\cdot}740$
11	$-{\cdot}6163x$	$-{\cdot}7875y$	$+z$	$+0{\cdot}322$	$=0$	7·2	$-0{\cdot}109$
12	$-{\cdot}0799x$	$-{\cdot}9968y$	$+z$	$+1{\cdot}093$	$=0$	9·3	$+0{\cdot}718$
13	$+{\cdot}5461x$	$-{\cdot}8377y$	$+z$	$+1{\cdot}450$	$=0$	3·8	$+0{\cdot}935$
14	$+{\cdot}8428x$	$-{\cdot}5383y$	$+z$	$+0{\cdot}561$	$=0$	5·0	$-0{\cdot}132$
15	$+{\cdot}9914x$	$-{\cdot}1305y$	$+z$	$+0{\cdot}489$	$=0$	5·8	$-0{\cdot}422$
16	$+{\cdot}9128x$	$+{\cdot}4083y$	$+z$	$-0{\cdot}063$	$=0$	8·8	$-1{\cdot}236$
17	$+{\cdot}5714x$	$+{\cdot}8207y$	$+z$	$+1{\cdot}029$	$=0$	13·2	$-0{\cdot}318$
18	$+{\cdot}0561x$	$+{\cdot}9984y$	$+z$	$+1{\cdot}009$	$=0$	17·5	$-0{\cdot}378$
19	$-{\cdot}4136x$	$+{\cdot}9104y$	$+z$	$+1{\cdot}021$	$=0$	26·0	$-0{\cdot}278$
20	$-{\cdot}8967x$	$+{\cdot}4425y$	$+z$	$-0{\cdot}409$	$=0$	6·1	$-1{\cdot}428$
21	$-{\cdot}9948x$	$+{\cdot}1022y$	$+z$	$-0{\cdot}049$	$=0$	5·8	$-0{\cdot}789$
22	$-{\cdot}9414x$	$-{\cdot}3374y$	$+z$	$-0{\cdot}271$	$=0$	9·8	$-0{\cdot}896$
23	$-{\cdot}6602x$	$-{\cdot}7511y$	$+z$	$-0{\cdot}139$	$=0$	6·0	$-0{\cdot}584$
24	$-{\cdot}1019x$	$-{\cdot}9948y$	$+z$	$-0{\cdot}426$	$=0$	8·3	$-0{\cdot}801$
25	$+{\cdot}6289x$	$-{\cdot}7775y$	$+z$	$+0{\cdot}584$	$=0$	4·0	$+0{\cdot}031$
26	$+{\cdot}8209x$	$-{\cdot}5712y$	$+z$	$+1{\cdot}395$	$=0$	5·5	$+0{\cdot}721$
27	$+{\cdot}9931x$	$-{\cdot}1175y$	$+z$	$+1{\cdot}150$	$=0$	3·1	$+0{\cdot}233$
28	$+{\cdot}9278x$	$+{\cdot}3730y$	$+z$	$+0{\cdot}741$	$=0$	3·7	$-0{\cdot}415$
29	$+{\cdot}5885x$	$+{\cdot}8085y$	$+z$	$+1{\cdot}681$	$=0$	8·9	$+0{\cdot}339$
30	$+{\cdot}0770x$	$+{\cdot}9970y$	$+z$	$+1{\cdot}785$	$=0$	12·5	$+0{\cdot}397$
31	$-{\cdot}4399x$	$+{\cdot}8980y$	$+z$	$+2{\cdot}015$	$=0$	9·6	$+0{\cdot}725$
32	$-{\cdot}7443x$	$+{\cdot}6678y$	$+z$	$+4{\cdot}469$	$=0$	1·8	$+3{\cdot}323$
33	$-{\cdot}9588x$	$-{\cdot}2840y$	$+z$	$+0{\cdot}100$	$=0$	2·0	$-0{\cdot}550$
34	$-{\cdot}6365x$	$-{\cdot}7713y$	$+z$	$-0{\cdot}609$	$=0$	4·7	$-1{\cdot}046$
35	$-{\cdot}1415x$	$-{\cdot}9899y$	$+z$	$-0{\cdot}890$	$=0$	4·8	$-1{\cdot}264$
36	$+{\cdot}8380x$	$-{\cdot}5456y$	$+z$	$-0{\cdot}599$	$=0$	3·2	$-1{\cdot}288$
37	$+{\cdot}9946x$	$-{\cdot}1042y$	$+z$	$-0{\cdot}744$	$=0$	2·3	$-1{\cdot}668$
38	$+{\cdot}9092x$	$+{\cdot}4163y$	$+z$	$-1{\cdot}373$	$=0$	6·7	$-2{\cdot}549$
39	$+{\cdot}5781x$	$+{\cdot}8160y$	$+z$	$+0{\cdot}486$	$=0$	9·8	$-0{\cdot}859$
40	$+{\cdot}0976x$	$+{\cdot}9952y$	$+z$	$+1{\cdot}010$	$=0$	17·0	$-0{\cdot}379$
41	$-{\cdot}9991x$	$+{\cdot}0422y$	$+z$	$-0{\cdot}272$	$=0$	6·2	$-1{\cdot}082$
42	$-{\cdot}9048x$	$-{\cdot}4258y$	$+z$	$+0{\cdot}008$	$=0$	6·5	$-0{\cdot}576$
43	$-{\cdot}6399x$	$-{\cdot}7685y$	$+z$	$-1{\cdot}330$	$=0$	6·5	$-1{\cdot}768$
44	$-{\cdot}1982x$	$-{\cdot}9802y$	$+z$	$+0{\cdot}961$	$=0$	8·4	$+0{\cdot}587$
45	$+{\cdot}6490x$	$-{\cdot}7608y$	$+z$	$+2{\cdot}291$	$=0$	0·7	$+1{\cdot}728$
46	$+{\cdot}8449x$	$-{\cdot}5348y$	$+z$	$+1{\cdot}474$	$=0$	2·4	$+0{\cdot}779$
47	$+{\cdot}9692x$	$-{\cdot}2462y$	$+z$	$+0{\cdot}797$	$=0$	3·2	$-0{\cdot}054$

No.	Equations of Condition.					Weights.	Residuals.
48	$+\cdot9181x$	$+\cdot3963y$	$+z$	$+0''\cdot120$	$=0$	5·1	$-1''\cdot047$
49	$+\cdot5955x$	$+\cdot8033y$	$+z$	$+1\cdot283$	$=0$	11·1	$-0\cdot057$
50	$+\cdot1022x$	$+\cdot9948y$	$+z$	$+2\cdot701$	$=0$	23·2	$+1\cdot312$
51	$-\cdot3557x$	$+\cdot9346y$	$+z$	$+1\cdot394$	$=0$	20·8	$+0\cdot078$
52	$-\cdot7711x$	$+\cdot6368y$	$+z$	$+1\cdot706$	$=0$	1·9	$+0\cdot578$
53	$-\cdot9952x$	$+\cdot0982y$	$+z$	$+1\cdot155$	$=0$	7·2	$+0\cdot317$
54	$-\cdot9400x$	$-\cdot3412y$	$+z$	$-0\cdot091$	$=0$	9·3	$-0\cdot714$
55	$-\cdot5738x$	$-\cdot8190y$	$+z$	$+0\cdot980$	$=0$	4·0	$+0\cdot561$
56	$-\cdot0799x$	$-\cdot9968y$	$+z$	$+0\cdot644$	$=0$	7·0	$+0\cdot267$
57	$+\cdot4697x$	$-\cdot8828y$	$+z$	$+1\cdot229$	$=0$	4·2	$+0\cdot744$
58	$+\cdot8231x$	$-\cdot5678y$	$+z$	$+0\cdot135$	$=0$	3·0	$-0\cdot541$
59	$+\cdot9970x$	$+\cdot0770y$	$+z$	$+0\cdot484$	$=0$	2·3	$-0\cdot531$
60	$+\cdot8663x$	$+\cdot4995y$	$+z$	$+0\cdot968$	$=0$	3·3	$-0\cdot246$
61	$+\cdot5575x$	$+\cdot8302y$	$+z$	$+1\cdot952$	$=0$	15·0	$+0\cdot602$
62	$+\cdot0398x$	$+\cdot9992y$	$+z$	$+1\cdot702$	$=0$	4·9	$+0\cdot316$
63	$-\cdot4731x$	$+\cdot8810y$	$+z$	$+2\cdot779$	$=0$	7·4	$+1\cdot501$
64	$-\cdot8100x$	$+\cdot5864y$	$+z$	$+2\cdot850$	$=0$	3·0	$+1\cdot751$
65	$-\cdot9948x$	$+\cdot1022y$	$+z$	$+2\cdot447$	$=0$	6·3	$+1\cdot607$
66	$-\cdot9227x$	$-\cdot3856y$	$+z$	$+0\cdot678$	$=0$	10·0	$+0\cdot065$
67	$-\cdot5915x$	$-\cdot8063y$	$+z$	$+2\cdot134$	$=0$	2·3	$+1\cdot710$
68	$-\cdot1722x$	$-\cdot9851y$	$+z$	$+0\cdot997$	$=0$	5·4	$+0\cdot623$
69	$+\cdot5721x$	$-\cdot8202y$	$+z$	$+0\cdot179$	$=0$	3·2	$-0\cdot347$
70	$+\cdot8499x$	$-\cdot5270y$	$+z$	$+1\cdot988$	$=0$	4·7	$+1\cdot289$
71	$+\cdot9988x$	$-\cdot0483y$	$+z$	$+1\cdot289$	$=0$	5·4	$+0\cdot337$
72	$+\cdot8420x$	$+\cdot5395y$	$+z$	$+0\cdot379$	$=0$	4·5	$-0\cdot852$
73	$+\cdot4452x$	$+\cdot8955y$	$+z$	$+1\cdot532$	$=0$	11·5	$+0\cdot160$
74	$+\cdot0105x$	$+\cdot9999y$	$+z$	$+1\cdot868$	$=0$	17·5	$+0\cdot485$
75	$-\cdot3945x$	$+\cdot9189y$	$+z$	$+1\cdot915$	$=0$	23·0	$+0\cdot610$
76	$-\cdot8175x$	$+\cdot5760y$	$+z$	$+2\cdot095$	$=0$	8·4	$+1\cdot001$
77	$-\cdot9995x$	$-\cdot0302y$	$+z$	$-0\cdot780$	$=0$	1·0	$-1\cdot553$
78	$-\cdot9031x$	$-\cdot4295y$	$+z$	$+0\cdot515$	$=0$	10·3	$-0\cdot068$
79	$-\cdot5664x$	$-\cdot8241y$	$+z$	$+1\cdot100$	$=0$	5·7	$+0\cdot683$
80	$-\cdot1063x$	$-\cdot9943y$	$+z$	$+1\cdot158$	$=0$	8·3	$+0\cdot783$
81	$+\cdot6115x$	$-\cdot7912y$	$+z$	$+0\cdot036$	$=0$	1·9	$-0\cdot508$
82	$+\cdot8183x$	$-\cdot5748y$	$+z$	$+0\cdot487$	$=0$	6·0	$-0\cdot185$
83	$+\cdot9926x$	$-\cdot1216y$	$+z$	$+1\cdot135$	$=0$	3·1	$+0\cdot220$
84	$+\cdot8619x$	$+\cdot5070y$	$+z$	$+0\cdot842$	$=0$	7·0	$-0\cdot375$
85	$+\cdot5220x$	$+\cdot8529y$	$+z$	$+0\cdot515$	$=0$	16·7	$-0\cdot843$
86	$+\cdot0976x$	$+\cdot9952y$	$+z$	$+0\cdot708$	$=0$	25·5	$-0\cdot681$
87	$-\cdot4062x$	$+\cdot9138y$	$+z$	$-0\cdot035$	$=0$	11·8	$-1\cdot336$

No.	Equations of Condition.					Weights.	Residuals.
88	$-{\cdot}8052x$	$+{\cdot}5930y$	$+z$	$-1''{\cdot}655$	$=0$	3·7	$-2''{\cdot}758$
89	$-{\cdot}9997x$	$+{\cdot}0253y$	$+z$	$-0{\cdot}131$	$=0$	4·8	$-0{\cdot}932$
90	$-{\cdot}9600x$	$-{\cdot}2801y$	$+z$	$+0{\cdot}100$	$=0$	3·0	$-0{\cdot}552$
91	$-{\cdot}5405x$	$-{\cdot}8414y$	$+z$	$+0{\cdot}075$	$=0$	4·7	$-0{\cdot}336$
92	$-{\cdot}1982x$	$-{\cdot}9802y$	$+z$	$-0{\cdot}326$	$=0$	4·6	$-0{\cdot}700$
93	$+{\cdot}8966x$	$-{\cdot}4428y$	$+z$	$+2{\cdot}365$	$=0$	8·0	$+1{\cdot}620$
94	$+{\cdot}9870x$	$-{\cdot}1607y$	$+z$	$+2{\cdot}351$	$=0$	3·9	$+1{\cdot}466$
95	$+{\cdot}9181x$	$+{\cdot}3963y$	$+z$	$+2{\cdot}110$	$=0$	2·9	$+0{\cdot}943$
96	$+{\cdot}5955x$	$+{\cdot}8033y$	$+z$	$+1{\cdot}450$	$=0$	16·2	$+0{\cdot}110$
97	$+{\cdot}1184x$	$+{\cdot}9930y$	$+z$	$+1{\cdot}840$	$=0$	13·5	$+0{\cdot}450$
98	$-{\cdot}3242x$	$+{\cdot}9460y$	$+z$	$+1{\cdot}921$	$=0$	17·4	$+0{\cdot}596$
99	$-{\cdot}7606x$	$+{\cdot}6492y$	$+z$	$+1{\cdot}861$	$=0$	7·1	$+0{\cdot}726$
100	$-{\cdot}9596x$	$+{\cdot}2812y$	$+z$	$+1{\cdot}287$	$=0$	1·0	$+0{\cdot}354$
101	$-{\cdot}8994x$	$-{\cdot}4371y$	$+z$	$+1{\cdot}461$	$=0$	6·5	$+0{\cdot}882$
102	$-{\cdot}6166x$	$-{\cdot}7873y$	$+z$	$+1{\cdot}080$	$=0$	8·1	$+0{\cdot}649$
103	$-{\cdot}1507x$	$-{\cdot}9886y$	$+z$	$+1{\cdot}262$	$=0$	10·1	$+0{\cdot}888$

Proceeding to solve these by the method of least squares, I find the normal equations:

$$
\begin{array}{lllll}
+313{\cdot}0289x & +\ 43{\cdot}8237y & -\ 23{\cdot}1768z & +\ 30''{\cdot}924 & =0 \\
+\ 43{\cdot}8237x & +495{\cdot}4996y & +237{\cdot}5829z & +461{\cdot}675 & =0 \\
-\ 23{\cdot}1768x & +237{\cdot}5829y & +809{\cdot}0z & +830{\cdot}524 & =0
\end{array}
$$

whence

$$
\begin{array}{lll}
x=-0''{\cdot}0941 & \text{with weight} & 306{\cdot}3438 \\
y=-0{\cdot}5003 & \quad ,, & 417{\cdot}5209 \\
z=-0{\cdot}8824 & \quad ,, & 688{\cdot}7679
\end{array}
$$

These values of x, y, and z have been substituted in the equations of condition, and the residuals (given in the last column above) formed. From them I find that the probable error of a determination of correction to tabular Ecliptic North Polar Distance of weight unity (on the assumption made in the formation of the equations of condition) is $\pm 1''{\cdot}5512$, and therefore

$$
\begin{array}{rl}
\text{Probable error of } x = & \pm 0''{\cdot}0886 \\
,, \quad y = & \pm 0{\cdot}0759 \\
,, \quad z = & \pm 0{\cdot}0591
\end{array}
$$

The above value of x indicates that, at the first point of *Aries*, the assumed ecliptic is north of the Sun's true path by $0''{\cdot}0941$, and therefore that the correction to the assumed (Newcomb's) system of right ascensions is

$$\frac{-0''{\cdot}0941}{15 \sin 23^\circ\ 27'} = -0^s{\cdot}0158 \pm 0^s{\cdot}0148.$$

The value of y indicates that the obliquity assumed in Hansen's and Olufsen's Tables ought to be diminished by $0''\cdot5003$.

The value of z shows that the mean of the observed distances from the pole to the ecliptic is too great by $0''\cdot8824$.

The corrections to the principal systems of right ascensions resulting from this discussion of Washington observations of the Sun are as follows:—

		s
Washington (1875–1883)	—American Ephemeris (Newcomb)	= −0·016
	—Berliner Jahrbuch (Auwers)	= 0·000
	—Greenwich (1880)	= +0·026
	—Pulkowa (1845)	= +0·003
	—Pulkowa (1865)	= −0·052
	—Conn. des Temps (1883)	= +0·029

Blackheath: July 1889.

Preliminary Spectroscopic Survey of Southern Stars, made at the Melbourne Observatory with a Maclean direct-vision Spectroscope on the 8-inch Equatorial.

(*Communicated by R. L. J. Ellery.*)

This survey is a rough reconnaissance preliminary to a more thorough examination of the spectra of southern stars it is intended to make by aid of the 4-foot reflector, and higher power spectroscopes. The list contains a hundred stars examined to the present time. The star-places are brought up to the epoch 1890, and the descriptions are copied from the actual notes taken at the time by Mr. P. Baracchi, assistant, who made the observations.

The "Maclean Spectroscope" while transmitting a maximum of light has low power, and, except in the case of red stars, is insufficient for stars below the 5th magnitude. For this reason, in the spectra of many stars of the 4th and 5th magnitude of Class II. (a) (Vogel Classification) no dark lines could be seen with certainty, and these are entered as having a continuous spectrum, while there can be little doubt fine dark lines will be seen with higher spectroscopic power. The Fraunhofer lines are freely made use of in the description, more for the sake of brevity than any pretension to accurate location of the features seen in the spectrum.

It is, however, hoped that even in this preliminary form the survey, when completed, will be of great use in mapping out theoretical outlines concerning the spectra of the southern stars, also in facilitating the spectroscopic work to be done with the great telescope, and, probably the most important of all, the detection of red stars.

No.	Name of Star.	R.A. 1890. h m s	N.P.D. 1890. ° ′	Description of Spectrum.
1	γ Argus	8 6 8	137 1	Spectrum with four bright lines. One in the blue about C, very bright. One in the green, also very bright. Two in the yellow, the one of which on the side of the red is very faint and the other very bright.
2	ε Argus	8 20 15	149 9	Dark line in the orange, dark line in the red, both conspicuous. Many other extremely faint dark lines.
3	δ Argus	8 41 40	144 18	Spectrum with two dark lines. One in the middle of the green, and the other in the blue. Green colour abounds. Very little red. Yellow almost absent.
4	β Argus	9 12 1	159 16	Spectrum with two dark lines. One in the middle of the green, thick; the other in the blue, also thick.
5	ι Argus	9 14 9	148 49	Spectrum with dark lines. One about F; one about G. Both conspicuous. Others extremely fine and faint.
6	κ Argus	9 18 43	144 33	Continuous spectrum. Green and blue abound.
7	η Crucis	12 1 9	154 0	Continuous spectrum. Green and blue abound. Hardly any yellow.
8	α Corvi	12 2 44	114 7	Dark line about F. Blue abounds. Hardly any yellow.
9	ε Corvi	12 4 28	112 0	Suspect extremely faint line about D, and some lines in the blue.
10	δ Crucis	12 9 18	148 8	Continuous spectrum.
11	γ Corvi	12 10 9	106 56	Spectrum with two thick prominent dark lines. One about G, the other in the extreme violet. Violet colour abounds.
12	ε Crucis	12 15 27	149 48	Continuous spectrum.
13	α Crucis	12 20 29	152 29	Spectrum with two dark thick lines. One about F; one about G.
14	δ Corvi	12 24 10	105 54	Spectrum with two very thick and black lines. One about G; the other at the end of the violet.
15	γ Crucis	12 25 4	146 29	Spectrum with flutings fading away gradually towards the red end. Two of these are in the red, very intense. One in the yellow, rather faint. Three in the blue, very prominent, and one, somewhat faint, in the green. Fine dark lines in the violet. Flutings easily resolved into dark lines grouped closer and closer together towards the violet end of the spectrum, where they terminate abruptly.

No.	Name of Star.	R.A. 1890. h m s	N.P.D. 1890. ° ′	Description of Spectrum.
16	γ Muscæ	12 25 55	161 31	Continuous spectrum.
17	η Corvi	12 26 24	105 35	Spectrum with only one dark line about G. Very little yellow. Blue predominates.
18	β Corvi	12 28 36	112 47	Spectrum with only one extremely dark faint line about C. Not well seen.
19	α Muscæ	12 30 38	158 32	Continuous spectrum.
20	β Muscæ	12 39 36	157 30	Spectrum with extremely faint lines in the blue and violet.
21	β Crucis	12 41 18	149 5	Continuous spectrum.
22	δ Muscæ	12 54 41	160 57	Continuous spectrum.
23	α Virginis	13 19 23	100 35	Continuous spectrum. Dividing spectrum in ten parts, four are violet, one blue, two green, one yellow and orange, two red. On one first-class night fine lines (dark) were suspected. Examined several times.
24	ε Centauri	13 32 55	142 54	Spectrum with very fine lines all over. Faintly seen.
25	ν Centauri	13 42 55	131 8	Continuous spectrum.
26	μ Centauri	13 43 0	131 56	Continuous spectrum.
27	κ Centauri	13 45 29	122 27	Continuous spectrum.
28	ζ Centauri	13 48 41	136 45	Continuous spectrum.
29	φ Centauri	13 51 35	131 34	Spectrum with very fine dark lines. Difficult.
30	β Centauri	13 56 4	149 50	?
31	θ Centauri	14 0 13	125 49	Faint dark line about D. Several very fine lines in the blue.
32	ι Lupi	14 12 22	135 33	Continuous spectrum.
33	η Sagittarii	14 28 32	131 40	Continuous spectrum.
34	α Centauri	14 32 6	150 22	Spectrum with very many dark lines all over. Dark lines about C, D, and G thick and conspicuous.

No.	Name of Star.	R.A. 1890.	N.P.D. 1890.	Description of Spectrum.
		h m s	° ′	
35	α Apodis	14 34 14	168 34	Spectrum with dark lines about D, *b*, F, and G all very faintly seen.
36	α Circini	14 33 39	154 30	Spectrum with many very fine lines all over. One dark line about F conspicuous. The fine lines are better defined and more easily seen in the red and orange than elsewhere. Blue colour predominates.
37	σ Lupi	14 34 37	136 55	Spectrum with very faint dark lines. Difficult.
38	β Lupi	14 51 20	132 41	Continuous spectrum.
39	κ Centauri	14 52 1	131 40	Continuous spectrum.
40	20 Libræ	14 57 40	114 51	Spectrum with flutings like γ Crucis. Three of these are in the red, the most intense of all. Two fainter ones in the green. One very prominent about G. Three in the violet very broad, but not so dark as those in the red. Fine dark lines interspersed.
41	ζ Lupi	15 4 25	141 40	Spectrum with very fine lines (suspected) all over.
42	γ Triang. Aust.	15 8 40	158 16	Spectrum with many faint dark lines. One about F conspicuous. Red and yellow in extremely small proportions.
43	δ Lupi	15 14 9	130 15	Continuous spectrum.
44	ϵ Lupi	15 15 13	134 17	Continuous spectrum.
45	γ Lupi	15 27 49	130 48	Continuous spectrum.
46	39 Libræ	15 30 20	117 46	Spectrum with dark bands in the green and blue (not easily seen). Faint dark line about D.
47	40 Libræ	15 31 54	119 25	Spectrum with a dark line about G and one about F. The blue extends over the greater part of the spectrum.
48	χ Lupi	15 43 58	123 17	Spectrum with a dark band about G. Blue predominates.
49	ξ Lupi	15 49 52	123 39	Very faint spectrum. Dark lines about F and G well seen. Other fainter dark lines very difficult.
50	ρ Lupi	15 50 5	118 55	Spectrum like that of ξ Lupi.

No.	Name of Star.	R.A. 1890. h m s	N.P.D. 1890. ° ′	Description of Spectrum.
51	π Scorpii	15 52 11	115 48	Spectrum with very fine lines. Uncertain. Violet predominates. Hardly any yellow.
52	η Lupi	15 52 50	128 5	Continuous spectrum. Blue predominates.
53	δ Scorpii	15 53 48	112 18	Continuous spectrum.
54	β′ Scorpii	15 59 2	109 30	Spectrum with faint dark lines in the blue and violet. Violet abounds.
55	θ Lupi	15 59 22	126 30	Continuous spectrum.
56	ω¹ Scorpii	16 0 23	110 22	Continuous spectrum. Blue and green predominate.
57	ω² Scorpii	16 0 37	110 34	Spectrum with extremely fine lines all over. Very faintly seen.
58	δ Triang. Aust.	16 5 26	153 24	?
59	ν Scorpii	16 5 36	109 10	Spectrum with several faint dark lines in the red and orange, and one more prominent about G.
60	α Scorpii	16 22 40	116 11	Spectrum with many dark lines, very thick and numerous in the red.
61	φ Ophiuchi	16 24 51	106 22	Continuous spectrum. Red very intense and in large proportion. Violet almost absent.
62	ζ Ophiuchi	16 31 6	100 21	Continuous spectrum.
63	α Triang. Aust.	16 37 1	158 49	Spectrum with a great many faint dark lines very difficult to see. One dark line in the yellow more prominent.
64	η Aræ	16 40 17	148 51	Spectrum with very faint dark lines about C and F. Very little yellow.
65	ε Scorpii	16 43 3	124 6	Continuous spectrum.
66	μ¹ Scorpii	16 44 25	127 51	Continuous spectrum.
67	μ² Scorpii	16 44 53	127 50	Continuous spectrum.
68	ζ¹ Scorpii	16 46 14	132 16	Continuous spectrum.
69	ζ² Scorpii	16 46 50	132 10	Continuous spectrum.
70	ζ Aræ	16 49 31	145 49	Spectrum with a dark line about D well seen; another about G suspected.

No.	Name of Star.	R.A. 1890.	N.P.D. 1890.	Description of Spectrum.
		h m s	° ′	
71	ϵ^1 Aræ	16 50 49	142 59	Spectrum with extremely fine lines in the green; also very fine dark line about G.
72	η Scorpii	17 4 16	133 5	Continuous spectrum.
73	ν Serpentis	17 14 38	102 44	Spectrum with a dark line about C. Difficult thick dark band about G, and a similar one towards the end of the violet.
74	β Aræ	17 16 9	145 25	Spectrum with dark lines about C, F, and G. One dark line in the yellow. C line difficult. Other faint lines suspected.
75	δ Aræ	17 21 11	150 35	Spectrum with very fine dark lines between F and G. Fine dark line about *b*. Dark band about G.
76	λ Scorpii	17 26 8	127 1	Faint dark lines in the red and orange. Dark line about G. Several other fainter lines difficult to see.
77	θ Scorpii	17 29 25	132 56	Spectrum with a dark line near F, and one in the orange.
78	η Pavonis	17 34 56	154 40	Continuous spectrum.
79	κ Scorpii	17 34 52	128 58	Continuous spectrum.
80	o Serpentis	17 35 14	102 49	Spectrum with faint dark line about C. Dark band about G, and a similar one in the violet. No line about F can be seen.
81	ι Scorpii	17 39 54	130 5	Continuous spectrum. Faint lines only suspected.
82	γ^1 Sagittarii	17 58 0	119 35	Continuous spectrum.
83	γ^2 Sagittarii	17 58 44	120 25	Continuous spectrum.
84	η Sagittarii	18 10 11	126 47	Spectrum with flutings fading away towards the red end. Two of these are in the red, very intense; two in the violet, also very intense, and one about G.
85	δ Sagittarii	18 13 57	119 52	Spectrum with extremely fine dark lines, uncertain.
86	ϵ Sagittarii	18 16 52	124 26	Spectrum with two dark bands; one about G, and one in the violet. Look like two single lines very thick and dark, but they give the idea of being formed by a group of dark lines close together. This remark applies to all cases where dark bands are mentioned.

No.	Name of Star.	R.A. 1890. h m s	N.P.D. 1890. ° ′	Description of Spectrum.
87	λ Sagittarii	18 21 11	115 29	Continuous spectrum. Yellow in extremely small proportion.
88	ϕ Sagittarii	18 38 47	117 6	Spectrum with a dark line about G, the only line distinctly seen. Others faint and uncertain.
89	σ Sagittarii	18 48 26	116 26	Spectrum with a dark line about F. One about G, and several between G and H.
90	ξ Sagittarii	18 51 10	111 15	Spectrum with very fine lines in the blue and violet.
91	o Sagittarii	18 58 5	111 54	Continuous spectrum.
92	τ Sagittarii	19 0 4	117 50	Spectrum with fine dark lines in the blue and violet.
93	π Sagittarii	19 3 13	111 12	Spectrum with a dark line about F. One about G. Several in the violet.
94	α Pavonis	20 16 56	147 5	Spectrum with very fine faint dark lines in the blue, violet, orange, and red. None seen in the yellow or green.
95	β Pavonis	20 35 3	156 36	Spectrum with a dark band in the violet. One distinct group of dark thick lines about F and a similar one about G. Several extremely fine lines between E and F. Green colour predominates. Yellow almost absent.
96	β Indi	20 46 13	148 52	Continuous spectrum. Yellow hardly seen.
97	γ Gruis	21 47 16	127 53	Spectrum with a faint dark line about C. Fine dark lines between E and *b*. Dark band or group of thick dark lines about F, a similar one about G, and another in the violet. Typical hydrogen lines. Violet predominates.
98	α Gruis	22 1 18	137 30	Spectrum with a faint dark line about C. Thick dark bands or groups of lines about F and G. One faint dark line about *b*. Several faint dark lines between G and H and beyond H.
99	δ^1 Gruis	22 22 42	134 2	Spectrum with two dark lines. One about F. One about G. No other line seen.
100	δ^2 Gruis	22 23 12	134 17	Spectrum with flutings like γ Crucis. Two of these are in the red, three in the blue, several in the violet, one in the yellow. Those in the red and blue are very striking. Fine dark lines in all colours,

Observations of Comets d, 1889 (Brooks), and e, 1889 (Davidson), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations on August 5, August 28, August 29, and September 25 were made with the East or Sheepshanks Equatorial, aperture 6·7 inches; and those on August 30 with the Lassell Reflector, aperture 24 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination.

Comet d, 1889 (Brooks)

Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Par.	Corr. for Refraction	☄−✱ N.P.D.	Corr. for Par.	Corr. for Refraction	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1889. d h m s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
Sept. 25 9 11 15	H.	+1 32·96	−0·22	0·00	+0 3·2	−7·6	0·0	6	23 51 1·53	95 16 49·4	a

Mean Place of Comparison Star.

	Star's Name.	R.A., 1889·0.	N.P.D., 1889·0.	Authority.
		h m s	° ′ ″	
a	W. B. XXIII. 973	23 49 26·34	95 17 9·6	Weisse's Bessel.

Notes.

The comet was exceedingly faint. No nucleus and no appearance of a part detached.

The observations are corrected for parallax and refraction.

Comet e, 1889 (Davidson).

Greenwich Mean Solar Time.	Observer.	☌−✱ R.A.	Corr. for Par.	Corr. for Refraction.	☌−✱ N.P.D.	Corr. for Par.	Corr. for Refraction.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1889. d h m s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
Aug. 5 10 21 30	C.	−0 0·55	+0·70	0·00	− 6 37·0	−14·9	−0·9	2	...	...	*a*
5 10 23 9	...	−1 20·20	+0·70	+0·10	−11 4·2	−14·9	−1·5	1	...	...	*b*
28 11 18 49	C.	−1 30·65	+0·50	0·00	+12 15·5	− 6·9	+0·8	2	...	...	*c*
29 9 10 1	...	+0 42·75	+0·40	0·00	+ 1 57·7	− 5·5	+0·1	2	...	...	*d*
29 9 21 4	...	+0 54·00	+0·40	0·00	− 8 55·6	− 5·5	−0·3	3	...	...	*e*
30 9 6 19	L.	−0 32·75	+0·36	0·00	− 4 38·8	− 5·3	−0·1	8	...	...	*f*

Mean Places of Comparison Stars.

	Star's Name.	R.A., 1889·0. h m s	N.P.D., 1889·0 ° ′	Authority.
a	Anonymous.			
b	Anonymous.			
c	B. D. +24°, 2985	16 11 7	65 39	Bonn Observations, vol. iv.
d	B. D. +24°, 2987	16 11 20	65 27	" " "
e	B. D. +24°, 2985	16 11 7	65 39	" " "
f	B. D. +24°, 2995	16 15 39	65 8	" " "

Notes.

The observations are corrected for parallax and refraction.

The initials C., L., and H. are those of Mr. Criswick, Mr. Lewis, and Mr. Hollis respectively.

Ephemerides of the Satellites of Saturn, 1889–90. By A. Marth.

In the following ephemerides the five inner satellites are assumed to move in circular orbits in the plane of the ring, the ascending node N and inclination J of which, in reference to the plane of the Earth's equator, are assumed to be

for 1890·0 $N = 126°·7048$. $J = 6°·9845$.

In the first table P denotes the position-angle of the minor axis of the ring, $L + 180°$ the planetocentric longitude of the Earth referred to the plane of the ring, $\Lambda + 180°$ that of the Sun, or $\Lambda - L$ the difference between the two. The last column contains the values of $\log \nu = 0·950 - \log \Delta$, the *Nautical Almanac* values of the distances Δ of the planet from the Earth being so altered as to take the equation of light into account.

Greenwich Noon.	P	L	Latitude of Earth above plane of Ring.	Latitude of Sun above plane of Ring.	Λ−L	Log ν.
1889. Oct. 24	353°·728	155°·275	− 8°·839	−11°·314	−4°·802	9·963853
29	·754	155·645	8·668	11·240	5·007	·967141
Nov. 3	353·777	155·986	− 8·513	−11·166	−5·182	9·970585
8	·798	156·295	8·375	11·091	5·325	·974166
13	·817	156·568	8·256	11·017	5·433	·977867
18	·834	156·805	8·155	10·943	5·505	·981667
23	·848	157·005	8·074	10·868	5·539	·985542
28	·859	157·166	8·013	10·794	5·534	·989464
Dec. 3	353·867	157·286	− 7·973	−10·719	−5·490	9·993404
8	·872	157·366	7·955	10·644	5·405	9·997331
13	·875	157·404	7·958	10·570	5·278	0·001217
18	·874	157·400	7·983	10·495	5·109	·005029
23	·870	157·354	8·029	10·420	4·899	·008732
28	·863	157·267	8·096	10·346	4·648	·012288
1890. Jan. 2	353·853	157·141	− 8·182	−10·271	−4·357	0·015663
7	·841	156·976	8·288	10·196	4·028	·018822
12	·826	156·775	8·412	10·121	3·663	·021732
17	·809	156·540	8·552	10·046	3·264	·024362
22	·790	156·274	8·706	9·971	2·835	·026680
27	·769	155·980	8·872	9·895	2·378	·028654
Feb. 1	353·746	155·664	− 9·048	− 9·820	−1·899	0·030264
6	·722	155·331	9·232	9·745	1·402	·031491
11	·698	154·984	9·421	9·670	0·891	·032321

Greenwich Noon.	P	L	Latitude of Earth above plane of Ring.	Latitude of Sun above plane of Ring.	A−L	Log ν.
1890. Feb. 16	353°·673	154°·627	− 9°·612	− 9°·594	−0°·370	0·032743
21	·648	154·265	9·803	9·519	+0·154	·032749
26	·624	153·904	9·991	9·443	0·677	·032341
Mar. 3	353·600	153·550	−10·173	− 9·368	+1·194	0·031526
8	·577	153·208	10·347	9·292	1·699	·030317
13	·555	152·882	10·511	9·216	2·187	·028729
18	·535	152·576	10·662	9·141	2·655	·026781
23	·517	152·295	10·800	9·065	3·099	·024496
28	·501	152·042	10·922	8·989	3·514	·021902
Apr. 2	353·487	151·821	−11·027	− 8·913	+3·897	0·019031
7	·475	151·634	11·113	8·837	4·246	·015914
12	·465	151·483	11·180	8·761	4·559	·012583
17	·458	151·370	11·228	8·685	4·834	·009069
22	·454	151·296	11·256	8·609	5·070	·005405
27	·452	151·262	11·264	8·533	5·265	0·001625
May 2	353·453	151·268	−11·251	− 8·457	+5·420	9·997764
7	·456	151·315	11·218	8·381	5·535	·993851
12	·462	151·401	11·166	8·304	5·610	·989914
17	·470	151·526	11·095	8·228	5·646	·985980
22	·481	151·690	11·004	8·152	5·643	·982075
27	·494	151·891	10·895	8·075	5·603	·978226
June 1	353·510	152·127	−10·769	− 7·999	+5·528	9·974457
6	·528	152·397	10·626	7·923	5·418	·970787
11	·548	152·700	10·466	7·846	5·276	·967232
16	·570	153·034	10·291	7·770	5·103	·963812
21	353·594	153·396	−10·104	− 7·693	+4·900	9·960543

The values of the apparent equatorial diameter of the ball and of the diameter of the outer rim of the ring depend on Bessel's determinations. The assumed proportion of the polar axis of the ball to the equatorial diameter is 0·900. The "phase" or the defect of illumination of the equatorial diameter is before opposition on the preceding limb and after opposition on the following limb.

In the tables for the five satellites a and b denote the semi-axes of the apparent orbits, $l-\text{L}$ the longitudes of the satellites in their orbits reckoned from the points which are in superior conjunction with the planet's centre or in opposition to the Earth in longitude. By adding to $l-\text{L}$ the value of L from the preceding table, the longitudes l are found. These longitudes, which

are the orbital longitudes from the ascending node added to the right ascension N of the ascending node, are corrected for the equation of light, and depend on the following assumed values, which refer to the time when the light from the planet arrives at the distance [0·950].

Greenwich Noon.	Mimas. l_1	Enceladus. l_2	Tethys. l_3	Dione. l_4	Rhea. l_5
1889, Oct. 24	294°·175	212°·280	152°·790	116°·400	291°·560
Nov. 23	233·995	174·234	113·735	102·450	162·263
Dec. 23	173·816	136·188	74·679	88·500	32·966
1890, Jan. 22	113·638	98·142	35·624	74·550	263·669
Feb. 21	53·460	60·096	356·568	60·600	134·372
Mar. 23	353·284	22·050	317·513	46·650	5·075
Apr. 22	293·110	344·004	278·457	32·700	235·778
May 22	232·936	305·958	239·402	18·750	106·481
June 21	172·763	267·912	200·346	4·800	337·184

The values of P, a, b, and $l-$L are to be interpolated directly for the times for which the apparent positions of the satellites are required, and the rectangular co-ordinates x and y reckoned parallel to the major and minor axis of the ring, or, if polar co-ordinates are wanted, the position-angles p and distances s of the satellites in reference to the planet's centre are then found by means of the formulæ:

$$s \sin(p-\mathrm{P}) = x = a \sin(l-\mathrm{L}),$$
$$s \cos(p-\mathrm{P}) = y = b \cos(l-\mathrm{L}).$$

Greenwich Noon.	Diameter of Bal Equat.	Phase.	Polar.	Axis of Ring. Major.	Minor.	Mimas. a_1	b_1	l_1-L	Diff.
1889. Oct. 24	16″·80	0″·029	15″·16	38″·73	5″·95	26″·46	−4″·07	137°·19	1909°·76
29	16·93	·032	15·28	39·02	5·88	26·66	4·02	246·95	·80
Nov. 3	17·06	·035	15·40	39·33	5·82	26·87	−3·98	356·75	·84
8	17·20	·037	15·52	39·66	5·78	27·10	3·95	106·59	·87
13	17·35	·039	15·65	40·00	5·74	27·33	3·92	216·46	·91
18	17·50	·040	15·79	40·35	5·72	27·57	3·91	326·37	·95
23	17·66	·041	15·93	40·71	5·72	27·82	3·91	76·32	1909·99
28	17·82	·041	16·07	41·08	5·73	28·07	3·91	186·31	1910·03
Dec. 3	17·98	·041	16·22	41·45	5·75	28·32	−3·93	296·34	·07
8	18·15	·040	16·37	41·83	5·79	28·58	3·96	46·41	·11
13	18·31	·039	16·52	42·21	5·84	28·84	3·99	156·52	·15
18	18·47	·037	16·66	42·58	5·91	29·09	4·04	266·67	·18
23	18·63	·034	16·80	42·94	6·00	29·34	4·10	16·85	·21
28	18·78	·031	16·94	43·30	6·10	29·58	4·17	127·06	·25

Greenwich Noon.		Diameter of Ball. Equat.	Phase.	Polar.	Axis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	$l_1 - L$	Diff.
1890.										
Jan.	2	18″·93	0″·027	17″·08	43″·63	6″·21	29″·81	−4″·24	237°·31	°
	7	19·07	·024	17·20	43·95	6·34	30·03	4·33	347·58	1910·27
	12	19·19	0·20	17·32	44·25	6·47	30·23	4·42	97·88	·30
	17	19·31	·016	17·43	44·52	6·62	30·42	4·52	208·19	·31
	22	19·41	·012	17·52	44·76	6·77	30·58	4·63	318·53	·34
	27	19·50	·009	17·60	44·96	6·93	30·72	4·74	68·88	·35
Feb.	1	19·58	·005	17 67	45·12	7·10	30·83	−4·85	179·23	·35
	6	19·63	·003	17·72	45·25	7·26	30·92	4·96	289·59	1910·36
	11	19·67	·001	17·76	45·34	7·42	30·98	5·07	39·94	·35
	16	19·69	...	17·78	45·38	7·58	31·01	5·18	150·29	·35
	21	19·69	...	17·78	45·38	7·73	31·01	5·28	260·62	·33
	26	19·67	·001	17·76	45·34	7·87	30·98	5·37	10·93	·31
Mar.	3	19·63	·002	17·73	45·26	7·99	30·92	−5·46	121·22	·29
	8	19·58	·004	17·69	45·13	8·11	30·84	5·54	231·48	1910·26
	13	19·51	·007	17·62	44·97	8·20	30·72	5·60	341·71	·23
	18	19·42	·010	17·55	44·77	8·28	30·58	5·66	91·91	·20
	23	19·32	·014	17·46	44·53	8·34	30·42	5·70	202·06	·15
	28	19·20	·018	17·35	44·26	8·39	30·24	5·73	312·17	·11
Apr.	2	19·08	·022	17·24	43·97	8·41	30·04	−5·75	62·24	·07
	7	18·94	·026	17 12	43·66	8·41	29·83	5·75	172·26	1910·02
	12	18·79	·030	16·99	43·33	8·40	29·60	5·74	282·24	1909·98
	17	18·64	·033	16·85	42·98	8·37	29·36	5·72	32·17	·93
	22	18·49	·036	16·71	42·62	8·32	29·12	5·68	142·05	·88
	27	18·33	·039	16·57	42·25	8·25	28·86	5·64	251·89	·84
May	2	18·16	·041	16·42	41·87	8·17	28·61	5·58	1·68	·79
	7	18·00	·042	16·27	41·50	8·07	28·35	5 52	111·43	1909·75
	12	17·84	·043	16·12	41·12	7·96	28·10	5·44	221·13	·70
	17	17·68	·043	15·98	40·75	7·84	27·84	5·36	330·79	·66
	22	17·52	·042	15·83	40·39	7·71	27·59	5·27	80·41	·62
	27	17·37	·041	15·69	40·03	7·57	27·35	5·17	190·00	·59
June	1	17·22	·040	15·56	39·68	7·42	27·11	−5·07	299·56	·56
	6	17·07	·038	15·43	39·35	7·26	26·89	4·96	59·08	1909·52
	11	16·93	·036	15·30	39·03	7·09	26·67	4·84	158·5	50
	16	16·80	·033	15·17	38·72	6·92	26·46	4·73	267·05	·47
	21	16·67	0·030	15·06	38·43	6·74	26·26	−4·62	17·50	·45

Greenwich Noon.	*Enceladus.* a_s	b_s	l_s-L	Diff.	*Tethys.* a_s	b_s	l_s-L	Diff.
1889.	″	″	°	°	″	″	°	°
Oct. 24	33·94	−5·22	55·83	1313·40	42·02	−6·46	356·66	953·20
29	34·20	5·15	289·23	·43	42·34	6·38	229·86	·23
Nov. 3	34·47	−5·10	162·66	·47	42·68	−6·32	103·09	·27
8	34·76	5·06	36·13	·51	43·03	6·27	336·36	·31
13	35·06	5·03	269·64	·55	43·40	6·23	209·67	·34
18	35·37	5·02	143·19	·58	43·78	6·21	83·01	·38
23	35·68	5·01	16·77	·62	44·17	6·20	316·39	·42
28	36·01	5·02	250·39	·67	44·57	6·21	189·81	·47
Dec. 3	36·33	−5·04	124·06	1313·70	44·98	−6·24	63·28	·50
8	36·66	5·07	357·76	·74	45·39	6·28	296·78	·54
13	37·00	5·12	231·50	·78	45·79	6·34	170·32	·58
18	37·32	5·18	105·28	·82	46·20	6·42	43·90	·62
23	37·64	5·26	339·10	·85	46·59	6·51	277·52	·65
28	37·95	5·34	212·95	·89	46·98	6·62	151·17	·69
1890.								
Jan. 2	38·24	−5·44	86·84	1313·92	47·34	−6·74	24·86	953·72
7	38·52	5·55	320·76	·94	47·69	6·87	258·58	·76
12	38·78	5·67	194·70	1313·97	48·01	7·02	132·34	·78
17	39·02	5·80	68·67	1314·00	48·30	7·18	6·12	·81
22	39·23	5·94	302·67	·01	48·56	7·35	239·93	·82
27	39·41	6·08	176·68	·02	48·78	7·52	113·75	·84
Feb. 1	39·55	−6·22	50·70	·03	48·96	−7·70	347·59	·85
6	39·66	6·36	284·73	·03	49·10	7·88	221·44	·86
11	39·74	6·50	158·76	·03	49·19	8·05	95·30	·86
16	39·78	6·64	32·79	·02	49·24	8·22	329·16	·85
21	39·78	6·77	266·81	1314·00	49·24	8·38	203·01	·84
26	39·74	6·89	140·81	1313·99	49·20	8·53	76·85	·83
Mar. 3	39·67	−7·01	14·80	·97	49·10	−8·67	310·68	953·81
8	39·56	7·11	248·77	·94	48·97	8·79	184·49	·78
13	39·41	7·19	122·71	·91	48·79	8·90	58·27	·76
18	39·24	7·26	356·62	·87	48·57	8·99	292·03	·72
23	39·03	7·31	230·49	·84	48·32	9·05	165·75	·69
28	38·80	7·35	104·33	·79	48·03	9·10	39·44	·65
Apr. 2	38·54	−7·37	338·12	1313·75	47·71	−9·13	273·09	·61
7	38·27	7·38	211·87	·71	47·37	9·13	146·70	·57
12	37·98	7·36	85·58	·67	47·01	9·11	20·27	·53
17	37·67	7·33	319·25	·62	46·63	9·08	253·80	·48
22	37·35	7·29	192·87	·58	46·24	9·03	127·28	·44

Greenwich Noon. 1890.	*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_3	b_3	l_3-L	Diff.
	″	″	°	°	″	″	°	°
Apr. 27	37·03	−7·23	66·45	·53	45·84	−8·95	0·72	·40
May 2	36·70	7·16	299·98	1313·49	45·43	8·86	234·12	953·35
7	36·37	7·08	173·47	·45	45·02	8·76	107·47	·31
12	36·04	6·98	46·92	·41	44·62	8·64	340·78	·27
17	35·72	6·87	280·33	·37	44·22	8·51	214·05	·24
22	35·40	6·76	153·70	·33	43·82	8·36	87·29	·20
27	35·09	−6·63	27·03	·30	43·43	−8·21	320·49	·17
June 1	34·78	6·50	260·33	·27	43·06	8·04	193·66	·13
6	34·49	6·36	133·60	·23	42·00	7·87	66·79	·10
11	34·21	6·21	6·83	·21	42·35	7·69	299·89	·07
16	33·94	6·06	240·04	1313·19	42·01	7·51	172·96	953·05
21	33·69	−5·91	113·23		41·70	−7·32	46·01	

Greenwich Noon. 1889.	*Dione.* a_4	b_4	l_4-L	Diff.	*Rhea.* a_5	b_5	l_5-L	Diff.
	″	″	°	°	″	″	°	°
Oct. 24	53·82	− 8·27	320·53	657·36	75·15	−11·55	135·93	398·11
29	54·23	8·17	257·89	·39	75·73	11·41	174·04	·14
Nov. 3	54·66	− 8·09	195·28	·43	76·33	−11·30	212·18	·18
8	55·11	8·03	132·71	·46	76·96	11·21	250·36	·22
13	55·58	7·98	70·17	·50	77·62	11·15	288·58	·25
18	56·07	7·95	7·67	·54	78·30	11·11	326·83	·29
23	56·57	7·95	305·21	·58	79·00	11·10	5·12	·32
28	57·09	7·96	242·79	·62	79·72	11·11	43·44	·37
Dec. 3	57·61	− 7·99	180·41	657·65	80·45	−11·16	81·81	398·41
8	58·13	8·04	118·06	·70	81·18	11·23	120·22	·45
13	58·65	8·12	55·76	·74	81·91	11·34	158·67	·49
18	59·17	8·22	353·50	·78	82·63	11·48	197·16	·53
23	59·67	8·33	291·28	·81	83·34	11·64	235·69	·57
28	60·16	8·47	229·09	·85	84·02	11·83	274·26	·61
1890. Jan. 2	60·63	− 8·63	166·94	657·89	84·68	−12·05	312·87	398·64
7	61·08	8·81	104·83	·92	85·30	12·30	351·51	·68
12	61·49	9·00	42·75	·95	85·87	12·56	30·19	·71
17	61·86	9·20	340·70	657·97	86·39	12·85	68·90	·74
22	62·19	9·41	278·67	658·00	86·85	13·15	107·64	·76
27	62·48	9·64	216·67	·01	87·25	13·46	146·40	·78
Feb. 1	62·71	− 9·86	154·68	·03	87·57	−13·77	185·18	398·80
6	62·89	10·09	92·71	·04	87·82	14·09	223·98	·80
11	63·01	10·31	30·75	·04	87·99	14·40	262·78	·81

Greenwich Noon.	Dione. a_4	b_4	l_4-L	Diff.	Rhea. a_5	b_5	l_5-L	Diff.
1890.	″	″	°	°	″	″	°	°
Feb. 16	63·07	−10·53	328·79	·03	88·07	−14·71	301·59	·81
21	63·07	10·74	266·82	·03	88·07	14·99	340·40	·80
26	63·01	10·93	204·85	·02	87·99	15·26	19·20	·80
Mar. 3	62·89	−11·11	142·87	658·00	87·83	−15·51	58·00	398·79
8	62·72	11·26	80·87	657·98	87·58	15·73	96·79	·76
13	62·49	11·40	18·85	·95	87·26	15·92	135·55	·74
18	62·21	11·51	316·80	·92	86·87	16·07	174·29	·71
23	61·88	11·60	254·72	·89	86·42	16·19	213·00	·68
28	61·51	11·66	192·61	·85	85·90	16·28	251·68	·65
Apr. 2	61·11	−11·69	130·46	657·81	85·34	−16·32	290·33	398·61
7	60·67	11·69	68·27	·78	84·73	16·33	328·94	·57
12	60·21	11·67	6·05	·74	84·08	16·30	7·51	·53
17	59·72	11·63	303·79	·69	83·40	16·24	46·04	·49
22	59·22	11·56	241·48	·65	82·70	16·14	84·53	·45
27	58·71	11·47	179·13	·61	81·98	16·01	122·98	·41
May 2	58·19	−11·35	116·74	657·57	81·26	−15·85	161·39	398·37
7	57·66	11·22	54·31	·53	80·53	15·67	199·76	·32
12	57·14	11·07	351·84	·49	79·80	15·45	238·08	·28
17	56·63	10·90	289·33	·44	79·08	15·22	276·36	·25
22	56·12	10·71	226·77	·41	78·37	14·96	314·61	·21
27	55·63	10·51	164·18	·38	77·68	14·68	352·82	·18
June 1	55·15	−10·30	101·56	·35	77·01	−14·39	31·00	·15
6	54·68	10·08	38·91	·31	76·36	14·08	69·15	·11
11	54·24	9·85	336·22	·28	75·74	13·76	107·26	·08
16	53·81	9·61	273·50	657·26	75·15	13·43	145·34	398·05
21	53·41	−9·37	210·76		74·58	−13·08	183·39	

Differences of right ascension and declination between Titan and Iapetus and the centre of Saturn.

Greenwich Noon.	Titan. a_6-A	δ_6-D	Iapetus. a_8-A	δ_8-D
	The differences from Oct. 24 to Nov. 4 are given on p. 427.			
1889.	s	″	s	″
Nov. 4	−12·09	−13·1	+ 2·70	+16·3
5	−12·08	−23·0	5·35	14·2
6	−10·36	−29·6	7·99	12·1
7	− 7·19	−32·1	10·59	9·9
8	− 2·99	−30·0	13·14	7·5
9	+ 1·65	−23·6	15·62	5·1

Greenwich Noon.	Titan. $a_s - A$	Titan. $\delta_s - D$	Iapetus. $a_s - A$	Iapetus. $\delta_s - D$
1889.	s	″	s	″
Nov. 10	+ 6·06	−13·7	+18·02	+ 2·7
11	+ 9·56	− 1·7	20·33	0·1
12	+11·55	+10·6	+22·54	− 2·5
13	+11·67	+21·1	24·63	5·0
14	+ 9·85	+28·1	26·58	7·6
15	+ 6·39	+30·4	28·39	10·2
16	+ 1·86	+27·6	30·05	12·8
17	− 2·99	+20·4	31·54	15·3
18	− 7·39	+10·0	32·85	17·8
19	−10·69	− 2·0	33·98	20·2
20	−12·43	−13·6	34·92	22·5
21	−12·39	−23·4	35·65	24·7
22	−10·60	−29·8	36·18	26·8
23	− 7·31	−32·1	+36·50	−28·7
24	− 2·98	−29·7	36·60	30·5
25	+ 1·80	−23·1	36·48	32·1
26	+ 6·33	−13·1	36·14	33·6
27	+ 9·87	− 1·0	35·57	34·8
28	+11·90	+11·3	34·78	35·8
29	+11·97	+21·7	33·78	36·6
30	+10·05	+28·5	32·56	37·2
Dec. 1	+ 6·45	+30·6	31·14	37·6
2	+ 1·76	+27·6	29·51	37·7
3	− 3·23	+20·1	+27·68	−37·5
4	− 7·74	+ 9·5	25·67	37·1
5	−11·09	− 2·6	23·49	36·5
6	−12·82	−14·4	21·14	35·6
7	−12·71	−24·2	18·64	34·4
8	−10·81	−30·5	16·01	33·0
9	− 7·37	−32·6	13·27	31·4
10	− 2·87	−30·1	10·43	29·6
11	+ 2·06	−23·1	7·50	27·5
12	+ 6·69	−12·7	4·51	25·2
13	+10·31	− 0·4	+ 1·48	−22·8
14	+12·29	+12·1	− 1·57	20·1
15	+12·27	+22·7	4·63	17·3
16	+10·20	+29·5	7·66	14·4
17	+ 6·42	+31·4	10·66	11·4

Greenwich Noon. 1889.	*Titan.* $a_s - A$	$\delta_s - D$	*Iapetus.* $a_s - A$	$\delta_s - D$
	s	″	s	″
Dec. 18	+ 1·55	+ 28·1	− 13·59	− 8·3
19	− 3·58	+ 20·3	16·44	5·1
20	− 8·18	+ 9·2	19·18	1·8
21	− 11·55	− 3·3	− 21·81	+ 1·4
22	− 13·23	− 15·4	24·29	4·7
23	− 13·02	− 25·4	26·62	7·9
24	− 10·95	− 31·8	28·78	11·0
25	− 7·33	− 33·8	30·75	14·1
26	− 2·65	− 31·0	32·51	17·1
27	+ 2·42	− 23·6	34·06	19·9
28	+ 7·15	− 12·7	35·39	22·6
29	+ 10·78	+ 0·2	36·48	25·2
30	+ 12·70	+ 13·2	37·33	27·6
31	+ 12·53	+ 24·0	37·93	29·7
32	+ 10·27	+ 31·0	− 38·29	+ 31·7

Approximate Greenwich times of conjunctions of the satellites with the centre of the planet or of their passages in the direction of the minor axis of the ring, "n," north, "s," south. The conjunctions of the three innermost satellites with the ends of the ring take place in the case of *Mimas* about $3^{\mathrm{h}}{\cdot}0$, *Enceladus* $3^{\mathrm{h}}{\cdot}2$, *Tethys* $3^{\mathrm{h}}{\cdot}5$ before and after the predicted conjunctions with the centre, which are not observable. For *Rhea* the times of the greatest elongations E. and W. are added.

1889.	h			h			h
Oct. 24	13·3 Rh. n.		Nov. 1	8·0 Tit. ☌ Iap. 3″		Nov. 6	23·8 Di. s.
25	16·1 Di. n.			9 Iap. Ecl. (*vide* p. 429)		7	2·8 Rh. n.
	16·4 Rh. w.			11·2 Rh. e.			4·3 Te. n.
	21·7 Te. s.			12·3 Di. s.		8	3·0 Te. s.
26	19·5 Rh. s.			12·4 Te. n.			5·9 Rh. w.
	20·4 Te. n.		2	11·0 Te. s.			8·6 Di. n.
27	0·9 Di. s.			14·3 Rh. n.			16·5 Tit. s. 26′
	19·1 Te. s.			16·5 Rh. ☌ Iap. 9″		9	1·6 Te. n.
	22·7 Rh. e.			21·1 Di. n.			9·0 Rh. s.
28	9·8 Di. n.			21·5 Di. ☌ Iap. 10″			17·5 Di. s.
	17·7 Te. n.			22·5 Iap. n. 18″		10	0·3 Te. s.
29	1·8 Rh. n.		3	7·2 Te. ☌ Iap. 10″			12·2 Rh. e.
	16·4 Te. s.			9·7 Te. n.			22·9 Te. n.
	18·6 Di. s.			17·4 Rh. w.		11	2·3 Di. n.
30	4·9 Rh. w.		4	6·1 Di. s.			15·3 Rh. n.
	15·0 Te. n.			8·3 Te. s.			21·6 Te. s.
31	3·5 Di. n.			20·5 Rh. s.		12	11·2 Di. s.
	8·0 Rh. s.		5	7·0 Te. n.			18·4 Rh. w.
	10·5 Tit. n. 26″			14·9 Di. n.			20·3 Te. n.
	13·6 $\ast$ $9^{\mathrm{m}}{\cdot}0$ s. 56″			23·7 Rh. e.		13	18·9 Te. s.
	13·7 Te. s.		6	5·7 Te. s.			20·0 Di. n.

1889.	h	
Nov. 13	21·5	Rh. s.
14	17·6	Te. n.
15	0·6	Rh. e.
	4·9	Di. s.
	16·2	Te. s.
16	3·8	Rh. n.
	10·1	Tit. n. 25″
	13·7	Di. n.
	14·9	Te. n.
17	6·9	Rh. w.
	13·5	Te. s.
	22·6	Di. s.
18	10·0	Rh. s.
	12·2	Te. n.
	19·8	En. s.
19	7·4	Di. n.
	10·9	Te. s.
	12·0	Mi. n.
	12·2	En. n.
	13·1	Rh. e.
20	9·5	Te. n.
	16·2	Rh. n.
	16·3	Di. s.
	21·1	En. n.
	22·0	Mi. s.
21	8·2	Te. s.
	13·6	En. s.
	19·3	Rh. w.
	20·6	Mi. s.
22	1·1	Di. n.
	6·8	Te. n.
	19·2	Mi. s.
	22·5	Rh. s.
	22·5	En. s.
23	5·5	Te. s.
	9·0	Di. s.
	14·9	En. n.
	17·8	Mi. s.
24	1·6	Rh. e.
	4·1	Te. n.
	16·0	Tit. s. 26″
	16·4	Mi. s.
	18·8	Di. n.
	23·8	En. n.
25	2·8	Te. s.
	4·7	Rh. n.
	15·1	Mi. s.
	16·2	En. s.
26	1·4	Te. n.
	3·7	Di. s.
	7·8	Rh. w.
	8·7	En. n.
	13·7	Mi. s.
27	0·1	Te. s.
	10·9	Rh. s.
	12·3	Mi. s.
	12·5	Di. n.
	17·6	En. n.
	22·8	Te. n.
28	10·9	Mi. s.
Nov. 28	14·0	Rh. e.
	21·4	Di. s.
	21·4	Te. s.
29	17·1	Rh. n.
	18·9	En. s.
	20·1	Te. n.
	20·8	Mi. n.
30	6·2	Di. n.
	11·3	En. n.
	18·7	Te. s.
	19·5	Mi. n.
	20·2	Rh. w.
Dec. 1	15·1	Di. s.
	17·4	Te. n.
	18·1	Mi. n.
	20·2	En. n.
	23·4	Rh. s.
2	9·3	Tit. n. 25″
	12·7	En. s.
	16·0	Te. s.
	16·7	Mi. n.
	23·9	Di. n.
3	2·5	Rh. e.
	14·7	Te. n.
	15·3	Mi. n.
	21·5	En. s.
4	5·6	Rh. n.
	8·8	Di. s.
	13·3	Te. s.
	13·9	Mi. n.
	14·0	En. n.
5	8·7	Rh. w.
	12·0	Te. n.
	12·5	Mi. n.
	17·6	Di. n.
	22·9	En. n.
6	10·6	Te. s.
	11·8	Rh. s.
	15·3	En. s.
	22·5	Mi. s.
7	2·5	Di. s.
	9·3	Te. n.
	14·9	Rh. e.
	21·1	Mi. s.
8	8·0	Te. s.
	11·3	Di. n.
	16·6	En. n.
	18·0	Rh. n.
	19·7	Mi. s.
9	6·5	Te. n.
	18·3	Mi. s.
	20·1	Di. s.
	21·1	Rh. w.
10	5·3	Te. s.
	15·0	Tit. s. 26″
	16·9	Mi. s.
	18·0	En. s.
11	0·2	Rh. s.
	3·8	Te. n.
	5·0	Di. n.
Dec. 11	10·4	En. n.
	15·5	Mi. s.
	16·7	Tit. ☌ Iap. 10″
12	2·6	Te. s.
	3·3	Rh. e.
	13·8	Di. s.
	14·2	Mi. s.
	19·3	En. n.
13	1·2	Te. n.
	6·4	Rh. n.
	10·4	Iap. s. 22″
	11·7	En. s.
	12·8	Mi. s.
	20·8	Te. ☌ Iap. 13″
	22·7	Di. n.
	23·9	Te. s.
14	9·5	Rh. w.
	11·4	Mi. s.
	20·6	En. s.
	21·1	Rh. ☌ Iap. 4″
	22·5	Te. n.
	22·7	Mi. n.
15	7·5	Di. s.
	12·6	Rh. s.
	13·1	En. n.
	21·2	Te. s.
	21·3	Mi. n.
16	15·7	Rh. e.
	16·3	Di. n.
	19·8	Te. n.
	19·9	Mi. n.
	21·9	En. n.
17	14·4	En. s.
	18·5	Te. s.
	18·6	Mi. n.
	18·8	Rh. n.
18	1·2	Di. s.
	8·1	Tit. n. 26″
	17·1	Te. n.
	17·2	Mi. n.
	21·9	Rh. w.
9	10·0	Di. n.
	15·7	En. n.
	15·8	Te. s.
	15·8	Mi. n.
20	1·0	Rh. s.
	8·1	En. s.
	14·4	Mi. n.
	14·4	Te. n.
	18·9	Di. s.
21	4·1	Rh. e.
	13·0	Mi. n.
	13·1	Te. s.
	17·0	En. s.
22	3·7	Di. n.
	7·2	Rh. n.
	9·5	En. n.
	11·6	Mi. n.
	11·7	Te. n.
23	10·2	Mi. n.

1889.	h		h		h
Dec. 23	10·3 Rh. w.	Dec. 26	6·3 Te. n.	Dec. 29	2·3 Te. s.
	10·4 Te. s.		12·1 En. n.		13·2 Mi. s.
	12·5 Di. s.		13·5 Tit. s. 27″		22·3 En. s.
	18·3 En. n.		17·4 Mi. s.	30	0·9 Te. n.
	21·5 Mi. s.		19·6 Rh. n.		4·9 Rh. e.
24	9·0 Te. n.	27	5·0 Te. s.		8·7 Di. n.
	10·8 En. s.		15·0 Di. n.		11·9 Mi. s.
	13·4 Rh. s.		16·0 Mi. s.		14·7 En. n.
	20·2 Mi. s.		21·0 En. n.		23·6 Te. s.
	21·4 Di. n.		22·7 Rh. w.	31	8·0 Rh. n.
25	7·7 Te. s.	28	3·6 Te. n.		10·5 Mi. s.
	16·5 Rh. e.		13·4 En. s.		17·5 Di. s.
	18·8 Mi. s.		14·6 Mi. s.		21·8 Mi. n.
	19·7 En. s.		23·9 Di. s.		22·2 Te. n.
26	6·2 Di. s.	29	1·8 Rh. s.		

The rest of the ephemeris will be published in the next number of the *Monthly Notices*.

Ephemeris of the Satellite of Neptune, 1889–90. By A. Marth.

Greenwich Noon.	P′	a	b	$u-$U	Diff.	U	B
1889.	°	″	″	°	°	°	°
Oct. 24	326·72	16·88	8·74	251·68	612·33	126·86	−31·13
Nov. 3	326·49	16·93	8·73	144·01	·30	127·12	31·04
13	326·25	16·96	8·72	36·31	·27	127·41	30·94
23	326·00	16·97	8·70	288·58	·26	127·71	30·83
Dec. 3	325·76	16·96	8·67	180·84	·26	128·02	30·72
13	325·52	16·93	8·63	73·10	·28	128·31	30·61
23	325·30	16·90	8·57	325·38	·30	128·57	30·51
1890.							
Jan. 2	325·11	16·84	8·52	217·68	612·34	128·80	−30·41
12	324·95	16·77	8·47	110·02	·38	128·99	30·33
22	324·83	16·69	8·41	2·40	·43	129·13	30·27
Feb. 1	324·76	16·60	8·36	254·83	·49	129·21	30·23
11	324·74	16·50	8·31	147·32	·55	129·23	30·21
21	324·77	16·41	8·26	39·87	·61	129·19	30·21
Mar. 3	324·85	16·31	8·22	292·48	·66	129·09	30·24
13	324·98	16·22	8·18	185·14	612·72	128·93	30·29
23	325·15	16·14	8·16	77·86		128·72	−30·36

The values of $u-$U, P′, a, b are to be interpolated directly for the times for which the apparent positions of the satellite are required, and the position-angles p and distances s of the satellite are then found by means of the formulæ

$$s \sin(\mathrm{P}'-p) = a \sin(u-\mathrm{U}),$$
$$s \cos(\mathrm{P}'-p) = b \cos(u-\mathrm{U}).$$

The satellite moves in the direction of *de*creasing position-angles, and will be at its greatest elongations (*nf* in pos. P′ + 90°, *sp* in pos. P′ − 90° at distance *a*), and at its conjunctions (*sup*erior in pos. P′, *inf*erior in pos. P′ − 180° at distance *b*) at the following Greenwich times:—

1889.	h		1889.	h	1890.	h		1890.	h
Oct. 24	7·2	nf.	Dec. 4	10·9	Jan. 14	14·7	nf.	Feb. 24	18·2
25	18·5	sup.	5	22·2	16	2·0	sup.	26	5·4
27	5·7	sp.	7	9·5	17	13·2	sp.	27	16·7
28	17·0	inf.	8	20·8	19	0·5	inf.	Mar. 1	3·9
30	4·3	nf.	10	8·1	20	11·8	nf.	2	15·2
31	15·6	sup.	11	19·3	21	23·1	sup.	4	2·4
Nov. 2	2·8	sp.	13	6·3	23	10·3	sp.	5	13·7
3	14·1	inf.	14	17·9	24	21·6	inf.	7	1·0
5	1·4	nf.	16	5·2	26	8·9	nf.	8	12·2
6	12·7	sup.	17	16·5	27	20·1	sup.	9	23·5
7	23·9	sp.	19	3·7	29	7·4	sp.	11	10·7
9	11·2	inf.	20	15·0	30	18·7	inf.	12	22·0
10	22·5	nf.	22	2·3	Feb. 1	5·9	nf.	14	9·2
12	9·8	sup.	23	13·6	2	17·2	sup.	15	20·5
13	21·0	sp.	25	0·8	4	4·5	sp.	17	7·7
15	8·3	inf.	26	12·1	5	15·7	inf.	18	19·0
16	19·6	nf.	27	23·4	7	3·0	nf.	20	6·2
18	6·9	sup.	29	10·7	8	14·3	sup.	21	17·5
19	18·2	sp.	1890.		10	1·5	sp.	23	4·8
21	5·4	inf.	Jan. 1	9·2	11	12·8	inf.	24	16·0
22	16·7	nf.	2	20·5	13	0·1	nf.	26	3·2
24	4·0	sup.	4	7·8	14	11·3	sup.	27	14·5
25	15·3	sp.	5	19·1	15	22·6	sp.	29	1·7
27	2·5	inf.	7	6·3	17	9·9	inf.	30	13·0
28	13·8	nf.	8	17·6	18	21·1	nf.	Apr. 1	0·2
30	1·1	sup.	10	4·9	20	8·4	sup.	2	11·5
Dec. 1	12·4	sp.	11	16·2	21	19·6	sp.		
2	23·7	inf.	13	3·4	23	6·9	inf.		

There ought to be no need to remind observers, who have the requisite instruments at their disposal, not to neglect to contribute the observations for the investigation of the question of the apparent changes in the position of the plane of the satellite's orbit, to which attention was called three years ago in the remarks attached to the ephemeris in vol. xlvi. Though a long period may have to elapse before a satisfactory determination of the constants on which these changes depend can be made, and though for even considerable portions of this period a lack of observations may not be of great importance, there ought to be no such lack just about the times when the nodes and inclinations reach their apparent maxima and minima, and in our present ignorance of these times it will be well to take care that some essential part of the evidence furnished by the observations may not be wanting.

In order the better to understand the nature of the problem which is to be solved, and to appreciate the present obstacles in the way of its solution, it may be serviceable to consider an analogous case.

The node and inclination of the orbit of the *Second Satellite of Jupiter* referred to the orbit of *Jupiter* have from 1850 to 1910 the following values, if the smaller terms (which may affect the inclination at most by 0°·032) are for the present purpose disregarded, and if the longitudes of the node are reckoned from the point of the equinox of 1880 :—

	Node.	Inclination.		Node.	Inclination.
1850·0	311°· 1	2°·617	1880·0	311°·90	2°·609
52	315·77	2·581	82	316·20	2·583
54	319·87	2·643	84	320·22	2·653
56	322·77	2·783	86	322·96	2·800
58	323·98	2·970	88	324·01	2·989
1860·0	323·56	3·165	1890·0	323·45	3·184
62	321·85	3·336	92	321·63	3·351
64	319·26	3·458	94	318·97	3·467
66	316 17	3·516	96	315·86	3·518
68	312·97	3·503	1898	312·66	3·497
1870·0	310·02	3·419	1900·0	309·76	3·408
72	307 71	3·277	02	307·53	3·260
74	306·44	3·093	04	306·38	3·074
76	306·60	2·897	06	306·71	2·879
78	308·46	2·723	08	308·73	2·709
1880·0	311·90	2·609	1910·0	312·30	2·596

A little consideration of these values shows that during these sixty years they have gone twice through all the phases of their variations, and that they furnish ample data for a determination of the five constants on which they depend: the node and inclination of the plane (nearly coinciding with that of *Jupiter's* equator) along which the satellite's orbit shifts at a uniform rate, the inclination of the orbit to this plane and the longitude of its node on this plane at a certain time, and the rate of its shifting. But suppose that, instead of knowing the values of the node and inclination of the satellite's orbit in reference to that of the planet for a length of time of double the period of their variations, they are known not even for half a period, but only for an uncertain small portion, during which no maximum or minimum has occurred, it is obvious that any attempt to solve the problem or guess at its solution would be premature. But it is also obvious that care must be taken not to lose important evidence for the future solution of the problem by want of observations at the right times.

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